BREED, TRANSPORT AND LAIRAGE EFFECTS ON ANIMAL WELFARE AND QUALITY OF NAMIBIAN BEEF

by

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own original work and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 19 February 2010

This thesis is written in article form for publication in Meat Science and therefore the referencing method used in this thesis is in line with that of the Meat Science journal.

Summary

Namibia by nature is very well suited for livestock production and is a net exporter of beef. Beef is currently exported to South Africa, the European Union (EU) and Japan while market access to the United States of America is being explored. Food safety, traceability and lately animal welfare are all aspects which are requested by Namibians trading partners when exporting meat to those countries. The first two aspects have been addressed with the introduction of the Farm Assured Namibian Beef scheme (FAN Meat) which also provides basic guidelines for animal welfare.

Beef in Namibia is produced from extensively managed enterprises which are privately owned and managed, or state owned and communally utilized. The events of handling and transport are considered stressful to all animals but especially so to extensively raised animals and their reaction to these events has the potential to severely infringe on their welfare. The aim of this study was to determine the effect of pre-, during, and post-transportation handling on animal welfare status under Namibian transport conditions. The study also investigated the influence of breed on the meat quality of Namibian beef.

The level of bruising recorded on slaughter was used to measure animal welfare. Interviews with producers were conducted to describe the pre-transport handling. Questionnaires that included variables considered as important indicators of animal welfare during transport were distributed to truck drivers. Observations of the off-loading event and animal behaviour were completed in lairage at the export abattoir in Windhoek. The variables that were identified as high risk factors and had a significant influence on the level of bruising under Namibian transport conditions include animal factors (i.e. breed type, age, sex, condition and subcutaneous fat cover), pre-transport handling (i.e. re-branding of animals), transport related risks (loading density and animals lying down during transit) as well as lairage factors (i.e. fit of truck floor to off-loading ramp, the way animals moved to holding pens, pen size and minimum environmental temperatures).

The influence of breed on meat tenderness and water-holding capacity of the *Longissimus dorsi* muscle of the four main beef breeds (i.e. Brahman, Bonsmara, Simbrah and Simmental), as well as the effect of different aging periods on meat quality (i.e. 2, 9, 16, 23, 30 & 37 days *post mortem*) were investigated. The Brahman differed significantly ($p < 0.05$) from the other three breeds in terms of all aging treatments; with higher Warner-Bratzler shear force values reported for this breed. Interactions between days *post mortem* and breed were found for the Simbrah, and Simmental breeds, which may be indicative of a delayed response to aging of meat samples obtained from Simbrah animals. This can possibly be ascribed to an increased calpastatin activity in these animals. Meat samples obtained from the Bonsmara steers showed the highest rate of tenderization, with this effect retained until day 30 *post mortem*.

Recommendations as pertaining to the ante mortem handling of cattle are made.

Opsomming

Namibië word gekenmerk deur toestande wat uitstekend vir diereproduksie is, met die land wat as ‘n netto uitvoerder van beesvleis beskou word. Vleis word na Suid-Afrika, die Europese Unie (EU) en Japan uitgevoer, met die moontlikheid van die Verenigde State van Amerika wat as ‘n uitvoermark ondersoek word. Voedselveiligheid, naspeurbaarheid en dierewelsyn is drie vereistes wat deur die invoerders van Namibiese vleis daargestel word. Die eerste twee vereistes is reeds deur die implementering van die *Farm Assured Namibian* beesvleis skema (*FAN Meat*) aangespreek, met die skema wat basiese riglyne vir dierewelsyn voorskryf.

Namibiese beesvleis word geproduseer onder grootskaalse ekstensiewe boerdery omstandighede, wat of privaat besit en bestuur word, of aan die regering behoort en deur plaaslike gemeenskappe benut word. Die invloed van hantering en vervoer is besonder stresvol vir diere en in besonder vir diere wat onder ekstensiewe omstandighede geproduseer word. Omdat diere onder ekstensiewe omstandighede ongewoond aan hantering en vervoer is, kan dié twee aksies ‘n ernstige impak op die welsyn van sulke diere hê. Die doelwit van die studie was om die invloed van hantering voor-, tydens en na-vervoer onder Namibiese vervoertoestande te ondersoek. Die invloed van ras op Namibiese beesvleiskwaliteit is ook ondersoek.

Die mate van kneusing waargeneem met slagting was as standaard gebruik om die welsynstatus van diere te bepaal. Onderhoude is met produsente gevoer om inligting oor die pre-vervoer toestande in te win. Vraelyste wat veranderlikes wat as belangrike indikators van dierewelsyn tydens vervoer beskou kan word, ingesluit het, is aan vragmotorbestuurders versprei. Waarnemings van die aflaai en verwante diergedrag was by die houfasiliteite van die uitvoer abattoir in Windhoek, waarnatoe die diere vervoer is, gedoen. Verskeie hoë risiko faktore wat ‘n betekenisvolle invloed op die mate van kneusing wat tydens vervoer opgedoen is, gehad het, is in die studie geïdentifiseer. Hierdie faktore het dierverwante eienskappe (d.i. ras, ouderdom, geslag, liggaamskondisie en onderhuidse vetvoorsiening), voorvervoer hantering (d.i. herbrandmerk van diere), vervoerverwante risiko’s (d.i. aantal diere per trok kompartement en diere wat tydens vervoer gaan lê), asook ontwerp van houfasiliteite (d.i. verbinding tussen trokvloer en laaibrug, die manier wat diere na houkampies beweeg het, grootte van houkampies en lae omgewingstemperature), ingesluit.

Die invloed van ras op die sagtheid en waterhouvermoë van die *Longissimus dorsi* spier van die vier hoof vleisbeesrasse (d.i. Brahman, Bonsmara, Simbrah en Simmentaler), asook verskillende verouderingstydperke op vleiskwaliteit (d.i. 2, 9, 16, 23, 30 en 37 dae *post mortem*) van die vier rasse is ondersoek. Die Brahman het betekenisvol ($p < 0.05$) van die ander drie rasse in terme van die effek van veroudering op vleiskwaliteit verskil, met hoë Warner-Bratzler skeursterkte waardes wat vir dié ras aangeteken is. ‘n Interaksie tussen aantal dae *post mortem* en ras is gevind vir die Simbrah en Simmentaler rasse, wat dui op ‘n vertraagde effek van vleisveroudering vir die Simbrah ras, moontlik as gevolg van ‘n hoër mate van kalpastatien aktiwiteit. Vleismonsters bekom van jong Bonsmara bulle het die grootste mate

van versagting getoon, met die voordeel wat waargeneem is tot dag 30 van die *post mortem* vleisveroudering.

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List of abbreviations

DF	Degrees of freedom
DFD	Dark, firm, dry meat
EU	European Union
FAN Meat	Farm Assured Namibian Meat scheme
GDP	Gross Domestic Product
N	Number of observations
p.m.	*post mortem*
pH_u	Ultimate pH
R^2	coefficient of determination
VCF	Veterinary Cordon Fence
WBSF	Warner Bratzler Shear Force

Chapter 1

Introduction

1.1 The Namibian challenge

Over the last decades animal welfare in livestock production has become an ever more important subject. This results mostly from the fact that current day consumers, especially in the developed countries, are not only interested in the source of their foodstuff but also in the impact its production has on the environment and the welfare of animals in livestock production systems. Furthermore, Governments of developed countries show a high degree of risk aversion on issues concerning health and wellbeing of their populations which can be seen in strict legislation and production policies for agricultural products and by-products to ensure food safety. The same production legislation is requested from countries who want to trade in agricultural goods (Cabrera *et al.*, 2007). This kind of legislation will in future include an increasing section on animal welfare requirements as governments react to the demands of their citizens.

Namibia by nature of its environment and climatic condition is well adapted to the extensive production of livestock. Eighty percent of its annual beef production is exported mainly to South Africa, Europe and Japan (Bowles, Paskin, Gutierrez & Kastarine, 2005). In 1999 the Farm Assured Namibian Meat (FAN Meat) scheme was launched in order to meet the requirements of the European Union for traceability and food safety. Next to improved traceability the scheme guarantees certain animal welfare and veterinary standards and complies with the requirements of the Sanitary and Phyto Sanitary Agreement (Anonymous, 2006).

In Namibia meat is produced from large, privately owned extensive farming operations or on state owned communally grazed range land. Both systems are characterized by low management inputs, large areas and often adverse climatic conditions. Assuring high animal welfare standards under extensive conditions poses a challenge to the industry, especially during transport and its concomitant increase in handling (Petherick, 2005).

The extensive livestock production practiced in Namibia pose a number of challenges to the animals used for meat production. Harsh environmental conditions, vast areas and external parasites call for well adapted breeds with good foraging abilities, resistance to tick and tick-borne diseases, high reproductive performance and low maintenance requirements. This led to the introduction of *Bos indicus* and *B. indicus* composite breeds next to indigenous and *Bos taurus* breed types used for beef production in Namibia. However, over the years these breed types were associated with poorer meat quality (Johnson, Huffman, Williams & Hargrove, 1990; Whipple, Koohmaraie, Dikeman, Crouse, Hunt & Klemm, 1990), especially tenderness and this lead to discrimination of meat sourced from these breeds (Pringle, Williams, Lamb, Johnson & West, 1997).

With the introduction of the FAN Meat scheme the Namibian meat industry demonstrated that it is capable of meeting EU standards. In order to maintain its trading status and in the light of exploring other market opportunities the next challenge for the industry will be to meet the animal welfare standards required of their trading partners and future trading partners (Anonymous, 2006).

1.2 Aims of research

This study was done to determine the influence of handling, transport and lairage on animal welfare and meat quality in the Namibian beef industry in order to provide information which could be used to develop a model code of practice adapted to the Namibian livestock transportation practices. It is the first scientific based approach that attempts to quantify the animal handling/welfare status of extensive livestock farming in Namibia. The level of bruising recorded on slaughter was used as an indication of poor welfare. With the aid of questionnaires and telephone interviews as well as observations in the lairage of the export abattoir in Windhoek the following areas were identified as critical to animal welfare during the event of transportation in Namibia:

1. Current Namibian farming practices and general preparation procedures for animals before transport to slaughter.
2. Transport elements including:
    - distances travelled and duration of journeys,
    - loading densities, and
    - road conditions.
3. Lairage effects:
    - off-loading and processing of animals on arrival,
    - animal behaviour.

In a separate study the effect of breed type on meat quality aspects such as water-holding capacity and tenderness were determined for the *Longissimus dorsi* muscle. The four major breed types slaughtered in Namibia, namely Brahman, Simbrah, Bonsmara and Simmental were included in this part of the trial. This part of the thesis stands outside the context of the rest of the text as it was impossible to link bruising and meat quality due to time and other physical constrains.

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Chapter 2

Literature review on animal welfare and quality of meat

2.1 Introduction

Animal welfare is a complex and emotional topic which is difficult to define and assess. Growing public interest in the welfare of animals and environmental impacts of livestock production systems has forced the industry to adopt and maintain high welfare standards while at the same time serving the consumers call for high quality yet reasonably priced products (Seng & Laporte, 2005). Furthermore it is a well documented fact that welfare and quality are related and that poor welfare practices will result in inferior meat quality (Wythes, & Shorthose, 1984; Eldridge, Warner, Winfield, Vowles, 1989; Broom, 2003)

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Brambell (1965) in a scientific report to the British government first described the 'Five Freedoms' that form the fundamental basis of any issues pertaining to farmed animal welfare. They can be summarized as: freedom from fear and distress; freedom to express normal behaviour; freedom from hunger and thirst; freedom from discomfort; and freedom from pain, injury and distress (Uetake, Ishiwata, Eguchi & Tanaka, 2008). During the life of all farm animals species there are times where these freedoms are violated and one of the most notable event is the time animals are transported. Transport of livestock removes the animal from its natural environment and exposes it to a variety of stressors such as increased handling, novel environments, regrouping/mixing, restricted movement, heat, cold, poor air quality, vibration, motion of the truck/ship, and noise. All these factors impinge on the welfare of the animal and can result in reduced product quality and even death (Ljungberg, Gebresenbet & Aradom, 2007). Furthermore the origin and environment (intensive vs. extensive production) an animal grew up in, determines its susceptibility to the above stressors (Grandin & Gallo, 2007).

This chapter summarizes the factors which affect animal welfare during handling and transportation and where applicable the effects these have on meat quality.

2.2 Animal welfare in extensive production systems

Animal welfare aspects which concern the extensive livestock production industry includes behavioural restriction; 'natural disasters'; nutrition; health; human-animal interactions (e.g. mustering and moving), as well as the consequences for welfare of the timing and frequency of handling; surgical procedures; identification; and predation (Petherick, 2005). This is by no means an exhaustive list of factors; however the welfare aspects of the actual transportation will be discussed later in this chapter.

As all other businesses, livestock production whether extensive or intensive, is driven by market forces, practicality and any animal welfare issues associated with it will also be bound to these forces. This implies that the livestock production industries have to assure high animal welfare standards within practical and financial constraints in order to maintain markets (Petherick, 2005).

It is generally accepted that animals raised in extensive production systems can perform most of their natural behaviour and are only restricted during times of handling and transportation. It is not known to which extent restriction of movement and prevention of grazing impinges on the welfare of the animals but Petherick and Rushen (1997) suggest that these events most likely jeopardise welfare if "(i) motivating factors result from internal changes in the animal, rather than from the environment (ii) motivation remains high even if the animal cannot perform the behaviour, and (iii) it is the performance of the behaviour that reduces the motivation, rather than the achievement of the consequences of the behaviour".

Good stockmanship is the key to minimising animal welfare problems in any livestock production system but especially so in extensive production where animals have little interaction with humans and most of these interactions are associated with adverse events like restraint, castration, dehorning and other forms of handling. According to Hemsworth (2003) there will be increasing demand from consumers to ensure the competency of stock people through-out the livestock production chain. Extensively reared cattle have larger flight zones and are not completely tame but will become calmer and easier to handle if they are trained to seeing people on foot, on horseback or in vehicles (Grandin, 2007b). Grandin (1997b) showed that that their first experience with human(s) makes a huge impression on animals and that a positive experience can influence the behaviour of animals in future. It has further been shown by different authors (Fordyce, Goddard, Tyler, Williams & Toleman, 1985; Voisinet, Grandin, Tatum, O'Connor & Struthers, 1997a; Fell, Colditz, Walker & Watson, 1999; Petherick, Holroyd, Doogan & Venus, 2002) that the temperament of cattle is a major factor related to the productivity of animals. Furthermore, cattle that are fearful, nervous, and flighty are difficult to handle increasing the risk of injuring themselves and/or handlers. It has also been suggested that bad tempered animals will elicit bad stockmanship in response (Petherick, 2005). Petherick *et al.* (2002) further showed that cattle with slow flight speeds are less susceptible to pre-slaughter stress, which has implications for meat quality.

The event of mustering can be very stressful to cattle, depending on the methods used and the ability of the stockman. Conventional methods of mustering cattle use noise and fear as a motivator for cattle to move and this can negatively affect welfare. However, a good stockman can reduce the amount of stress to a minimum. Different breeds show different behavioural characteristics that affect handling. Pure-bred *B. indicus* and *B. indicus* crosses have a greater tendency to follow a person or lead animal (Grandin, 2007a) and so do many of the indigenous Sanga cattle (*Bos taurus africanus*). This behaviour can be utilised to move animals with minimal stress.

Other welfare problems that can arise during mustering include exhaustion, dehydration and heat stress. Especially young calves and heavily pregnant cows are susceptible to these stressors. Therefore animals should be moved during the cooler parts of the day and the slowest moving animal should determine the speed of movement of the whole herd (Petherick, 2005). *B. indicus* and *B. taurus africanus* breeds are generally better adapted to heat and will cope better with extreme temperatures (Strydom, 2008).

It may be debatable whether those in charge of livestock are responsible to safeguard animals during the occurrence of natural disasters like droughts and bushfires which are integral parts of the Namibian ecosystem. However, firebreaks can be established to try and limit the spread of fires and contingency drought planning and lower stocking densities can be used to decrease the impact natural disasters have on animals. In some countries it is not permissible that animals die of thirst and/or hunger and if necessary the animals must be euthanized (Anonymous, 2001).

Namibia is considered the driest country of sub-Saharan Africa with a mean annual rainfall of 270 mm. There are wide regional variations in annual rainfall, from more than 700 mm at the eastern end of the Caprivi strip to less than 20 mm in the western Namib and coastal areas (Sweet, 1998). Rainfall is seasonal and very variable between years and droughts are a common occurrence.

As a result of the seasonal rainfall in Namibia pasture quantity and quality follow a cyclical pattern and periodic live weight and body condition changes in livestock are a common occurrence. Similar conditions are found in Northern Australia where Winks (1984) reported losses of up to 10% and more depending on the duration of the dry period, the class of stock, their body condition entering the dry season, and the quality and quantity of pasture available. Frisch and Vercoe (1984) found that tropically adapted beef cattle genotypes are more resistant to the effects of poor nutrition and it can therefore be argued that the welfare of these animals is less impaired compared to non-adapted breeds. During severe droughts, weight losses can be so severe as to lead to the death of animals. In Namibia mineral supplementation is needed throughout most of the year in most areas of the country in order to counteract deficiencies of the natural veldt. This improves animal health as well as animal condition and prevents deficiencies from occurring.

In most extensive livestock production operations preventative medication is practiced as it is rather difficult to pick up single sick animals in large herds and vast areas. The failure to detect sick or injured animals leads to increased duration of suffering and pain which impairs animal welfare. Even where regular inspections of animals take place at water points it is difficult even for an experienced stockperson to detect health-problems at an early stage. Treating sick or injured animals poses practical difficulties in extensive systems since facilities that permit safe restraint; close examination and treatment are not always available (Petherick, 2005). Where treatment is deemed uneconomical animals are often left to recover while those that are gravely sick are euthanized. In the case of adult bovine, euthanization is mostly done using a firearm but in some cases and especially with younger animals cutting the throat of the animal is still common practice. In Namibia the new, revised guidelines (personal communications, Dr Thalwitzer, 2009) supplied by the FAN Meat scheme (the local traceability system) recommend the use of a firearm in case of emergency slaughter or euthanization for all animals.

Tropically adapted breeds like the *B.indicus* and *B. taurus africanus* breeds are mostly resistant to tick bite fever (Bonsma, 1980; Schoeman, 1989), yet all breeds of cattle may be at risk of sever disease if exposed to virulent strains of *Anaplasma marginale* (Bock, de Vos, Kingston & McLellan, 1997). Vaccination programs are often used to improve herd health and thereby prevent deaths (Petherick, 2005).

Dehorning, branding and castration are “surgical” procedures that form part of the handling procedure in extensive production systems and which do impinge on welfare but also improve the welfare at a later stage in the animal’s life. These procedures should be conducted as early as possible in an animal’s life because greater restraint is required for older animals. Robertson, Kent and Molony (1994) and Boesch, Steiner, Gygax & Stauffacher (2008) found little postural difference (indicative of discomfort and pain) in 6-day old calves castrated with a burdizzo and sham treated controls while Thüer, Mellema, Doherr, Wechsler, Nuss and Steiner (2007) who measured behaviour and cortisol response in calves castrated at age 3 to 4 weeks found castration to be painful, especially when rubber ring castration was practised. Wounds caused during dehorning and castration will be larger on older calves and are therefore associated with greater blood loss (particularly in the case of dehorning), longer wound healing times and possibly, greater pain (Petherick, 2005). An alternative to dehorning is the use of polled genotypes. In Namibia branding of cattle is compulsory as it is still the most reliable and economical form of identification. Hot iron branding at weaning (around 8 months of age) is the most common method practised. Furthermore, since the invention of the traceability system (FAN Meat) all animals carry a single, individual ear-tag as identification.

Predation is another factor which affects welfare of farmed animal species in extensive management systems. The predators that are most common on Namibia farms include leopard, cheetah, lynx and jackal. It is debatable whether the person responsible for livestock should be responsible to safeguard them from predation. It is in the economic interest of any producer to prevent unnecessary losses in his/her herd. However, predators are an integral part of the environment where livestock is produced and the livestock species form a natural part of the food chain in these habitats. Earlier approaches to predator control on farmland in Namibia have led to the local extinction of some predator species like lions and African Wild Dogs and the near extinction of hyenas. A balance should be found between safeguarding stock and preserving wild species. Under the current trend, where consumers are not only interested in the source of their meat but also the impact its production has on the environment, humane forms of predator control become more and more important. One retailer in South Africa started a campaign in 2008, to introduce predator-friendly meat to the South African market. Together with the Landmark Foundation it released a book called “Predators on livestock farms: A practical Manual for Non-Lethal, Holistic, Ecologically Acceptable and Ethical Management” (Smuts, 2008) which contains guidelines for livestock producers. The retailer already has a ‘free range meat’ brand which is sourced from Namibia and supplied by producers who sign a declaration that they have not used gin traps, poisons or pack hunting to control predators.

For extensively raised animals the close proximity with humans during handling, restriction in movement and novelty of handling facilities will cause stress to the animal. In addition to physical injuries caused by animals trying to avoid these situations the experienced stress leads to physiological changes. Glycogen depletion in the muscle is caused by physical activity and/or emotional excitement (McVeigh, Tarrant & Harrington, 1982) and results in dark-cutting beef as a direct result. This meat quality defect is associated with a high pH, poor appearance (dark colour) and ease of spoilage (Lawrie, 1998).

2.3 Effects of transport on animal welfare and meat quality

The stressors associated with transport and handling cause physiological changes and the combination of different factors will lead to decreased welfare, reduced meat quality and therefore economic losses to the industry. Any form of handling, and driving are associated with physical damage which is manifested in bruising, torn skins and broken bones and in extreme cases can lead to the death of an animal. Psychological stress is caused by novel environments and regrouping, which can lead to increased social interaction and result in physical exhaustion. Furthermore, the event of transportation involves the withdrawal of feed and water for extended periods of time leading to weight loss and dehydration (Knowles, 1999). Poor welfare in addition to the cost to the animals also results in inferior meat quality which is manifested in decreased tenderness, poor water-holding capacity and colour.

Bruising accounts for considerable losses in the livestock industry (Hails 1978; Grandin 1980a; Wythes & Shorthose 1984; Eldridge & Winfield 1988; McNally & Warriss 1996). Except for the direct loss in carcass weight, the removal of bruised tissue is time consuming and can add to labour costs and reduce line speeds and thus throughput of an abattoir (McNally & Warriss 1996). Grandin (1983) defined bruising as "an impact injury that can occur at any stage in the transportation chain and may be attributed to poor design of handling facilities, ignorant and abusive stockmanship or poor road driving techniques during transportation". The degree of bruising observed on slaughter can be used as an indication of the welfare status of the animals (Strappini, Metz, Gallo & Kemp, 2009). The drawback of evaluating bruising as a welfare measure lies in the fact that it only becomes visible after slaughter yet the injury can happen at any point of the transport chain. Although it is possible to determine age of bruising to some degree by the colour of the bruise (Gracey & Collins, 1992) the transport events happen in such a sequence that it is difficult to pinpoint a bruise to any specific event.

The physiological changes observed in cattle during transport are caused by mechanisms in the animal's body to maintain homeostasis. These physiological changes can include increases in body temperature, heart and respiration rate. Any form of fear activates the pituitary-adrenal axis, resulting in increased circulating levels of cortisol, glucose, and free fatty acids. Transport is also associated with muscle exertion (cattle stand during transport) which is manifested in increased levels of muscle enzymes, especially creatine kinase, in the blood (Broom, 2003). Table 1 gives an overview of the stressors associated with transport and handling and the affect it has on the physiological state of the animal. Many of these physiological variables are used in research to measure animal welfare status.

Table 2.1 Commonly used physiological indicators of stress during transport (adapted from Broom, 2003)

Stressor	**Physiological variable**
Measured in blood or other body fluids	
Food deprivation	↑ FFA, ↑β-OHB, ↓ glucose, ↑ urea
Dehydration	↑ Osmolality, ↑ total protein, ↑ albumin, ↑ PCV
Physical exertion	↑ CK, ↑ lactate
Fear/arousal	↑ Cortisol, ↑ PCV
Motion sickness	↑ Vasopressin
Other measures	
Fear/arousal and physical pain	↑ Heart rate, ↑ heart rate variability, ↑ respiration rate
Hypothermia/hyperthermia	Body temperature, skin temperature

FFA = free fatty acids; β-OHB = β-hydroxybutyrate; PCV = packed-cell volume; CK = creatine kinase.

Kent and Ewbank (1983) and Tarrant *et al.* Tarrant, Kenny, Harrington and Murphy (1992) reported increases in the number of white blood cells and neutrophils and a decrease in the numbers of lymphocytes, eosinophils and monocytes in transported cattle. The changes in these blood constituents indicate that the stressors alter the immune system of animals. The concomitant loss of resistance to infection is believed to cause bovine respiratory disease complex, also referred to as ‘shipping fever’ which often leads to deaths in feedlot cattle after transport (Irwin, McConnell, Coleman & Wilcox, 1997).

Food and water deprivation cause weight loss in all farm animal species. The severity of this weight loss is determined by different factors like time off feed, time off water, ambient temperatures, diet, duration of transport as well as age and sex of the animal. The degree of weight loss reported in the literature varies greatly but it has been well established that deprivation of food and water coupled with transport will increase this loss. Shorthose and Wythes (1988) estimate weight loss to amount to 0.75% of an animal’s initial weight per day. It has been shown that in adult cattle the majority of weight loss during the initial 24-48 hours of fasting originates from excretion of gastrointestinal contents and urine. The gut contents can account for 12-25 % of the animals live weight (Grandin & Gallo, 2007). After 48 hours off feed and water, tissue catabolism and dehydration further increase weight loss (Ferguson & Warner, 2008). If water is available during periods off feed the live weight loss will be less severe (Knowles, 1999). On the other hand when reviewing the literature it seems that ruminants can cope relatively well with feed and water deprivation for periods up to 48 hours (Ferguson & Warner, 2008). In terms of welfare, water deprivation has a more profound impact than feed deprivation as it can lead to dehydration within 24-48 hours.

In terms of hygiene a period off feed before slaughter is believed to decrease risks of microbial contamination during evisceration caused by rumen rupture. However, Whythes and Shorthose (1984) and Wythes, Smith, Arthur and Round (1984) showed that gutfill does not necessarily determine the ease of evisceration. These findings are supported by Ferguson, Shaw and Stark (2007) who determined the impact of reduced lairage time on meat quality.

In a review of the road transport of cattle, Knowles (1999) noted that mortalities are especially high for calves while it seems that adult cattle are more resilient to it than most other livestock species. Little information is available on overall mortalities during road transport for different countries. Henning (1993) reported figures of 0.01% for deaths during transport in South Africa for 1980 and no deaths in a study done during the early 1990’s.

Meat quality of a carcass is ultimately a function of meat/muscle pH. More specifically, the rate of pH decline inter-related with the rate of temperature decline, as well as the ultimate pH (pH_u) influences tenderness, colour, and water-holding capacity (WHC). During the conversion of muscle to meat glycogen is converted to lactic acid which accumulates in the muscle causing the pH to drop. The pH_u is therefore dependent on the glycogen reserves in the muscle of live animals. Any form of stress *ante mortem* decreases the glycogen reserves in the muscles thereby decreasing their ability for *post mortem* glycolysis resulting in higher pH_u. Glycogen breakdown *ante mortem* is triggered by two mechanisms, increased adrenaline in stressful situations (short-term stress) and/or strenuous muscle activity (long-term stress) (Grandin & Gallo 2007).

High pH_u in beef is associated with an unattractive dark colour referred to as dark-cutting or dry, firm, dark (DFD) meat. Apart from its poor appearance, the high pH of DFD meat enhances the growth of bacteria (Lawrie 1998). This lowers shelf-live and renders it unsuitable for the vacuum-packed fresh meat market (Grandin & Gallo 2007).

Other meat quality aspects that have been linked to transport and handling include decreased tenderness (Schaefer, Jones, Tong & Young, 1990) and decreased palatability (Jeremiah, Schaefer & Gibson, 1992; Schaefer & Jeremiah 1992). Fernandez, Monin, Culioli, Legrand and Quilichini (1996) for example reported that sensory quality of veal was lower after long distance transport of 20 week old calves.

2.4 Handling associated with transport

Ante mortem handling of livestock creates stress to the animals. The amount of stress an animal experiences depends on its sex, age, breed, genetics, temperament and previous experience of handling. Additionally, the attitude of the person handling the animals has a great influence on their welfare. Some people perceive animals as sentient and therefore able to experience pain while others might consider them as objects respected according to their economic value (Broom, 2007). These attitudes influence how people handle animals and can result in poor welfare or cause little stress depending on the person doing the job.

Grandin (1980b) in her review 'livestock behaviour as related to handling facility design', notes that where stock people are conscious of inherent animal behaviour in terms of flight zone, point of balance, herd instincts and visual perception and incorporate that knowledge into their handling practices animal welfare can be improved. She further describes how animal behaviour should be incorporated into handling facility design in order to facilitate animal flow and decrease stress levels and injuries.

In practice, it can often be observed that animals react differently to the same stressors. These differences can partly be attributed to genetic differences associated with breeds. In general, the *B.indicus* breeds are more excitable than the *B. taurus* and react more strongly to novel environments (Tulloh, 1961). On the other hand, the reaction of individual animals may be influenced by inherent temperament, degree of tameness, environment wherein the animal is raised, earlier handling experiences and contact with humans (Grandin, 1997a).

2.5 External variables of transport

There are numerous external variables which influence the degree of stress animals experience during transport. The variables that have been extensively described are loading densities, distance and duration of journey, and the handling of animals *ante mortem*. However, there are also other variables which affect the levels of stress experienced by the animal such as weather (temperature and relative humidity), driving style, and road conditions.

Vehicle design influences the ease of loading and off-loading procedures and animal comfort during the journey. Flooring should be such as to improve foothold and the transport crates should be free of any protruding objects which could cause bruising and injuries. Especially in warm countries heat stress can severely influence welfare during transport and provisions should be made for good ventilation inside the loading area. The vehicle design and maintenance recommendations given by Grandin and Gallo (2007) facilitate high welfare standards they however demand high financial inputs and this might be feasible where large trucking companies transport large number of cattle while it will be hard to implement in countries where the trucking is done by small companies or private individuals.

Transportation subjects livestock to novel environments and it has been found that at the beginning of a journey the animals are more anxious and restless and that they urinate and defecate more frequently (Knowles, 1999). As the animals start to adjust to the new environment, to social regrouping, to confinement on the truck, to confinement and motion, the initial number of social interactions is high but gradually decreases (Knowles, 1999) while the frequency of urination and plasma cortisol levels increased with successive stages of transport (Kenny & Tarrant, 1987 a, b). The increased amount of soiling on the truck floor can be detrimental to the balance of the animals and Wythes (1985) advised that withholding water six hours prior to loading would facilitate drier truck floors and thus improve footing for the animals.

Cattle generally prefer to stand during short periods of transport. On long journeys the tendency to lie down increases indicating that the animals become tired (Kent & Ewebank; 1985; Knowles, 1998; Warriss, 1998). Loading densities will determine whether animals are able to lie down without risking injury and further destabilizing other animals (Tarrant *et al.*, 1992; Warriss *et al.*, 1995). Once the truck is set in motion the animals will align themselves either across the direction of travel or parallel to it while animals tend to avoid the diagonal orientations (Eldridge, Winfield & Cahill, 1988; Tarrant, Kenny and Harrington 1988; Tarrant *et al*., 1992). At high stocking densities Tarrant *et al.* (1988, 1992) found that adaptation of the preferred orientation was hampered and that the orientation was mostly dictated by the rectangular shape of the pen. However, the diagonal orientations were avoided even at low space allowances.

Although stocking densities have been studied by many researchers there is no single definition/value of an optimum space allowance. Many countries have some or other recommendation(s)/legislation(s) concerning stocking densities and most of these are based on animal size and practical experience (Knowles, 1999). The British Farm Animal Welfare Council (FAWC) (Anonymous, 1991) advised the following formula for calculating the minimum space allowance per animal based on live weights: $A = 0.021W^{0.67}$, where A is the area in square meters and W is the weight of the animal in kg. From this the Council recommended 360 kg/m^2 as a guideline value for maximum stocking density of adult cattle. Another formula was developed by Randall (1993), $A = 0.01W^{0.78}$. The latter formula is more rigid in its space allowances and Randall recommended the use of the FAWC especially when larger animals are transported. Randall however cautioned that these formulae should only be applied to journeys of less than five hours.

Table 2 gives the recommended space allowances of the Livestock Trucking Guide (Grandin 1981, revised 2001) published by the National Institute for Animal Agriculture (NIAA), USA. It should be noted that these guidelines distinguish between polled and horned animals. The space allowances recommended in the Namibian FAN Meat Manual are as follows: mature cattle 1.0 m^2 (minimum); calves 0.3 m^2, and sheep/goats 0.4 m^2 (Anonymous, 2002). The differences in recommended space allowances often reflect the different production systems, preferred breeds and dominant frame-sizes of the animals in different countries.

Table 2.2 Recommended space allowance for cattle transported by road (adapted from Grandin, 1981a)

Feedlot fed steers or Cows (kg)	Horned/tipped or more than 10% horned & tipped (m^2)	No horns (polled) (m^2)
360	1.01	0.97
454	1.20	1.11
545	1.42	1.35
635	1.76	1.67

Tarrant *et al*. (1988) determined the effect of three different stocking densities (196, 312, 591 kg/m^2) for 600 kg steers on a four hour journey. In a second study by Tarrant *et al.* (1992), 600 kg steers were transported for 24 hours at stocking densities of approximately 450, 500 and 600 kg/m^2. During the long-distance transport the steers started to lie down after 16 hours of transport if the space allowance permitted such behaviour but at the high stocking density of 600 kg/m^2 the animals were unable to lie down as they had too little room to move and risked being trampled. In both studies of Tarrant *et al.* (1988 & 1992) there were strong indications that at 600 kg/m^2 the wellbeing of the steers was adversely affected. Bruising increased with stocking density and severe bruise scores were only recorded for the high density groups. More falls were observed at high stocking densities and floored animals struggled to regain their feet thereby destabilizing other group members. Loss of balance could be linked to driving events, especially braking, shifting gears and cornering.

By measuring blood glucocorticoid content Tarrant *et al.* (1992) found that plasma cortisol increased with increasing loading densities indicating an increase in stress for the animals. The haematological data also indicated stress responses as increases of white blood cell count and neutrophil numbers, as well as reductions in lymphocytes and eosinophil numbers were recorded.

In an experiment by Eldridge *et al* (1988), the importance of stocking density, pen size and road condition on the heart rate and behaviour of cattle in transport in south-eastern Australia was investigated. They found that animals with more space allowance (1.14 m^2) had higher heart rates than those transported at higher loading densities (0.89 m^2) indicating that the latter group was less physically and psychologically stressed. These findings are consistent with the general belief that animals that are transported at low stocking densities struggle to remain standing and are more prone to slips and falls. These seemingly contradictory findings of Tarrant *et al.* (1992) and Eldridge *et al.* (1988) could be explained by the difference in live weight of the transported animals and the fact that the stocking densities used by the latter did not reach critical limits. Other factors might also have played a role.

In terms of animal welfare the length of a journey is more important than the actual distance covered (Warriss, 1990). Due to changes in the slaughter industry in Europe and North America the distance animals travel to slaughter is increasing (Warriss, 1995; Speer, Slack & Troyer, 2001), while in other parts of the world long-distance transport is dictated by the structure of the industry and the size of the countries. Most countries have codes which determine how long animals may be transported without rest stops however, as with stocking densities there is no single recommendation. Some authors have shown that short rest stops can actually increase the amount of stress because of off-loading, loading and too little time for the animals to drink and eat. It is also questionable whether short rest stops (of one hour) will give the animals any time to rest and rebuild their strength (energy reserves) (Knowles *et al*., 1999).

Eldridge and Winfield (1988) showed that dark-cutting (DFD) was less likely to occur over short transport distances. This might be due to the fact that short journeys are less taxing for the animals in terms of maintaining balance than longer journeys provided that handling and driving does not increase stress levels unnecessarily. Traumatic events such as when an animal goes down, can lead to dark-cutting even during short-distance transport (Tarrant *et al.*, 1992). Long-distance road transport has been linked to increased incidences of dark-cutting in beef (Tarrant *et al.*, 1992; Honkavaara, Rintasalo, Ylonen & Pudas, 2003; Gallo, Lizondo & Knowles, 2003).

Increases in red blood cell count, haemoglobin, total protein and packed cell volume are indicators of dehydration in animals (Blood, Radostits & Henderson, 1983). Tarrant *et al.* (1992) reported an increase in plasma creatine kinase after 24 hours of transport, indicating physical fatigue in the steers. They also noticed that the steers were noticeably tired after a 24 hour journey. After off-loading most animals drank and then lay down in lairage. The muscle pH of the animals was higher compared to those that had been transported for one hour indicating that muscle glycogen had been depleted thus increasing the chances for DFD meat. From this the authors concluded that journeys of 24 hours and longer would be detrimental to the welfare of the animals. In another study, cattle of 350 kg live weight were transported for 10 and 15 hours. Little differences were found between the treatment groups and it was concluded that 15 hours of transport is acceptable in terms of welfare (Warriss *et al.*, 1995).

In the two studies by Tarrant *et al.* (1988 & 1992) carcass bruising was similar in cattle transported for 4 hours and 24 hours. Similar findings were reported by Hartung (2003) who noted that as animals adapt to transportation, the number of bruises and injuries decrease and that the highest incidence occurred during the initial stages of a journey. On the other hand, Minka and Ayo (2007) who studied transport bruising in three West African breeds, the White Fulani (WF), Red Bororo (RB) and Sokoto Gudale (SG) reported that bruising increased with journey time. These apparently contradictory findings could be ascribed to the fact that the animals in the latter trial had horns. Shaw, Baxter and Ramsey (1976) and Wythes (1985) showed that horned cattle had twice as much bruising compared to polled animals. Cutting the tips of the horns does not reduce the amount of bruising and space allowances should be adjusted when horned animals are transported (Grandin 1981).

Journey time is greatly determined by road conditions and the latter strongly influences driving style. Both road conditions and driving style affect the amount of bruising observed at abattoirs (Grandin & Gallo 2007). In general it can be said that adult cattle prefer to stand during transport up to 24 hours (Knowels *et al*., 1999) which might be due to their size and weight while calves will lie down during transport where loading densities permit. Stocking density greatly influences the animal's ability to shift its position. Shifts in position allow the animal to counteract vehicle movement and thus maintain balance. Eldridge and Winfield (1988) and Tarrant *et al.* (1988, 1992) reported increased levels of bruising at high stocking densities. Moreover these authors observed that the three main driving events which lead to loss of balance are cornering, braking and gear changes. According to (Grandin & Gallo 2007) efforts are made by some countries to improve welfare during livestock transport by passing legislation and educating producers, drivers and handlers.

Ambient temperature and humidity during transport influence the extent of shrinkage and hot weather will result in higher weight loss. Two-thirds of this loss is due to evaporative water loss from the lungs and this explains why more excitable cattle lose more weight than calmer animals (Grandin, 1981). The temperature inside the truck depends on the design of the vehicle (ventilation), the loading density and whether the truck is moving or stationary. Heat builds up rapidly in a stationary vehicle and any stops should therefore be kept as short as possible (Grandin & Gallo 2007). In Namibia, where all cattle transport trucks are open ventilation is not required. However, during the rainy season it should be kept in mind that an animal's ability to cope with cold is greatly reduced when the animal becomes wet. In her 'Livestock Trucking Guide' Grandin (1981) includes a chart 'Livestock Weather Safety Index' which gives an overview of temperature and humidity and their impact on transported cattle.

Scanga, Belk, Tatum, Grandin and Smith (1998) reported increases in dark-cutting carcasses when temperatures fluctuated by more than 5.6ºC in one day or temperatures above 35ºC were observed 24-72 hours before slaughter. In Namibia fluctuations between minimum and maximum temperatures during winter can be higher than 5.6ºC and during summer temperatures can exceed 35ºC.

Livestock markets pose another variable which will affect handling and transport times. In many countries animals are marketed through livestock auctions. This implies that these animals are subjected to more handling and often longer and repeated transportation compared to animals sourced directly from the farm. Eldridge, Barnett, McCausland, Millar & Vowles (1984) described significantly fewer and smaller bruises in cattle transported directly from the farm than those sold through livestock markets. Hoffman, Spire, Schwenke and Unruh (1998) found similar results in a study on mature beef cows. Little is known about the number of animals marketed through livestock markets before slaughter in Namibia. Livestock auctions do however form part of the Namibian meat industry and therefore it can be assumed that the same welfare problems arise in this part of the industry.

2.6 External variables of lairage

The time animals spend in lairage is determined by a country's legislation and/or code of practice. In some countries animals are slaughtered on the day of arrival while in others animals have to stand overnight before being slaughtered (Ferguson & Warner, 2008). The original intent of keeping animals in lairage after transport was to give them a chance to rest and recover from the journey, while also ensuring a continuous throughput on the slaughter lines.

However, replenishing glycogen reserves in lairage is unfeasible as it would require extended lairage periods where feed and water are provided to the animals. The novelty of lairage in itself, may prove stressful to the animals (McVeigh & Tarrant, 1982) thus adding to the stress of transport. Furthermore, long lairage periods would bring about high costs and increase the risk of microbial contamination and spread of diseases. Tadich, Gallo, Bustamante, Schwerter and van Schaik (2005) showed that there is no beneficial effect on the welfare of the animals by increasing lairage periods while Gallo *et al.* (2003) noted that increased journey times coupled with increased lairage times further increased the incidence of dark-cutting carcasses. Similar results were reported by other authors (Warner, Truscot, Eldridge & Franz, 1998; Matzke, Alps, Strasser & Gunter, 1985; Fabiansson, Erichsen & Reutersward, 1984; Wjada & Wichlacz 1984; Augustini, Fischer & Schon, 1980). On the other hand, Ferguson *et al.* (2007) found no differences in shear force or compression values of non-aged or 14 day aged *Longissimus* muscle of animals kept for 3 or 18 hours in lairage indicating that meat tenderness was not affected by lairage periods up to 18 hours. Although any pre-slaughter stress inevitably leads to losses in muscle glycogen (Warriss, 1990), Ferguson *et al.* (2007) failed to find any further depletion of muscle glycogen after an additional 15 hours of lairage. They explained these findings by the fact that McVeigh and Tarrant (1982) showed that glycogen depletion rates in cattle during fasting are relatively slow (1.3 µmoles/g.day).

The provision of water in lairage however does improve meat quality. Whytes (1982) showed that even after long journeys in hot weather (25-36ºC) muscle water content would increase if the animals had access to water for 3.5 hours or longer before slaughter. However, novel environments, unfamiliar watering facilities and different water sources (taste) will contribute to the variability of drinking behaviour (Ferguson & Warner, 2008). Some authors have indicated the benefits of oral electrolytes in counteracting weight loss and dehydration during transport and further indicated that animals familiar with electrolytes in their water source will accept new water sources more readily if the same electrolytes are added (Schaefer, Jones & Stanley, 1997).

Social interactions often caused by novel environment, regrouping and mixing of unfamiliar animals in lairage can further increase the stress an animal experiences before slaughter. According to Bartos, Franc, Rehak and Stipkova (1993) regrouping and mixing are the major causes for DFD meat. Mounting and riding as well as fighting have been shown to increase the amount of bruising before slaughter and deplete glycogen reserves in the muscles leading to increased muscle pH. Kenny and Tarrant (1987c) used electrified overhead wire grids to prevent mounting in lairage and found that this eliminated the incidence of DFD meat.

Eldridge, Warner, Winfield and Vowels (1989) monitored cattle behaviour in lairage, and observed more movement in those animals situated near noisy environments than those in quieter areas. The former group also showed an increase in bruising compared to the latter. From this they recommended that lairage management should aim to minimise movement past resting animals in order to reduce stress and bruising during lairage.

In a study on sheep, Jacob, Pethick and Chapman (2005) found no difference in consumer sensory scores for five day aged meat from animals kept in lairage for 0, 1, or 2 days before slaughter.

2.7 Breed differences and meat quality

Apart from pre-slaughter stress and the interventions such as chilling regime adopted *post mortem*, other factors which can influences meet quality are breed, sex and age. In general it can be said that tenderness decreases with age due to structural changes of the collagen cross links in the connective tissue. Furthermore, intact males will produce tougher meat compared to castrated males and these are generally tougher than females provided that comparisons are done at the same physiological age. Breed can influence meat quality due to inherent genetic parameters as well as due to different temperaments. It should however be noted that within breed variation in tenderness is larger than between breed variation.

All Namibian cattle breeds, except for composite breeds, can be allocated to one of the following three breed groups, the *B. indicus* (Zebu), *B. taurus* (British and continental breeds) or the *B. taurus africanus* (Sanga or indigenous Southern African Breeds). The *B. indicus* and the *B. taurus africanus* breeds are better adapted to harsher climates compared to the *B. taurus* breeds which originate from more temperate areas. The Zebu and Sanga are better adapted to deal with ticks, tick related diseases and heat and in general have better reproductive performance in hot arid areas such as Namibia (Strydom, 2008).

The most commonly utilized breeds for beef production in Namibia are the Bonsmara, Brahman, Simbrah and Simmental although other breeds are also farmed with. The following breeds are registered with the Namibian Stud Breeders Association: Angus, Beefmaster, Bonsmara, Brahman, Brangus, Braunvieh, Charolais, Dexter, Gelbvieh, Hereford, Limousin, Nguni, Pinzgauer, Santa Gertrudis and South Devon. Most commercial herds use cross bred animals for beef production and for this reason animals used in this investigation were categorised by breed types reflective of the commercial beef production industry of Namibia.

The oldest imported breed is the Simmental which was introduced in 1893 directly from Germany (Anonymous, 2009a). Namibia, then still German South West Africa, was the first country outside Germany which established the Simmental breed. The main aim was to introduce a breed that would improve milk and meat production of the indigenous breeds. Over the years the Namibian Simmental changed from a dual purpose breed to a primarily beef producing breed. Today the animals are well adapted to the Namibian environment.

The first pure bred Brahmans were introduced to Namibia in 1954 by Mr Cranz, who purchased these animals in the USA. The main reason for introducing the Brahman was that it was hardy and resilient to heat and illnesses and would be ideal for crossbreeding with the *B. taurus* breeds that dominated in Namibia at that time (Anonymous, 2004).

The Bonsmara was developed in the 1980's by Professor Bonsma at the Mara Livestock Research Station in South Africa. It is a composite breed, made out of 5/8 indigenous Afrikaner cows and 3/8 exotic Shorthorn and Hereford bulls (Bonsma, 1980). The aim of this breeding program was to develop a breed that combined the production traits of the European breeds with the hardiness of the indigenous breeds. Today, the Bonsmara has grown to be numerically the strongest beef breed in South Africa.

The Simbrah breed had its origin in the USA where the first Simmental semen was imported in the 60's. The semen was used on Brahman dams and the performance of the F1 generation was reported as outstanding. The first F1 Simmental/Brahman crosses were registered in 1986 with the Simmental Breeders Association of Southern Africa (Anonymous, 2009b).

Although the *B. indicus* breeds are well adapted to harsher environments they have been associated with inferior meat tenderness compared to the European breeds. Studies by Whipple, Koohmaraie, Dikeman, Crouse, Hunt and Klemm (1990), Shackleford, Koohmaraie, Cundiff, Gregory, Rohrer and Savell (1994) and Wulf, Tatum, Green, Morgan, Golden and Smith (1996) found that genetic differences in beef tenderness can be linked to the variation in the rate and extent of muscle proteolysis which takes place during post mortem storage of fresh beef. The primary proteolytic enzyme system involved in post mortem tenderization of aged beef is the calpain system, which consists of two calcium requiring enzymes, μ-calpain and m-calpain, as well as an inhibitor, calpastatin (Koohmaraie, 1996). Calpastatin activity, measured 24 hours post mortem, is one variable that can be used to predict meat tenderness. Various studies showed that calpastatin activity is higher in *B. indicus* and *B. indicus* composite animals compared to *B. taurus* (Ferguson, Jiang, Hearnshaw, Rymill & Thompson, 2000; Riley et al., 2003; Riley et al., 2005) and that this is one reason why meat from the former tends to be tougher Crouse, Cundiff, Koch, Koohmaraie & Seideman, 1989; Johnson, Huffman, Williams & Hargrove, 1990). In two separate studies Shackleford *et al*. (1994) and Wulf *et al*. (1996) reported that both tenderness and calpastatin activity are moderately to highly heritable (within breeds) and that the two traits are correlated genetically. Cundiff (1992) suggested that the above mentioned could be used in breeding programs to improve tenderness in *B. indicus* and *B. indicus* composite breeds. O'Connor, Tatum, Wulf, Green and Smith (1997) studied the genetic effects on beef tenderness in *B. indicus* composite and *B. taurus* cattle and summarised strategies for improving tenderness of beef produced by heat tolerant cattle as follows: I) use post-mortem aging periods of adequate length for all cuts of *B. indicus* cattle; II) select for improved beef tenderness (via progeny testing) in *B. indicus* breeds; and III) substituted tropically adapted *B. taurus* germplasm for *B. indicus* breeding in the development of heat-tolerant composite breeds.

Tenderness is most probably the one meat quality aspect which shows the largest amount of variation and one of the important contributors to this variation is among-animal variation in temperament (Brown, Carstens, Fox, Randel & Holloway 2004; Voisinet et al., 1997a; Voisinet, Grandin, O'Connor, Tatum &, Deesing, 1997b). Grandin (2007a) reported that an animal's first experience with handling has a profound effect on its reaction to any future handling experiences. Furthermore, animals raised under extensive production systems are less accustomed to handling and in general have larger flight zones than those raised in close contact with humans (Grandin, 2007a). Although cattle do adapt to certain production systems, for example feedlots, Behrends *et al*. (2008) found that the first reaction of an animal to handling reflects best how it will react to novel environments. In this study the authors were able to show that animals got used to the feedlot processes and calmed down after some time but that once these animals were sent to slaughter those animals with initial high scores for temperament on entering the feedlot reacted strongest to the new disruption. Although animals within breeds differ widely in temperament there are also differences between breeds in terms of temperament. As mentioned earlier there is a general perception that *B. indicus* animals are more temperamental and difficult to handle.

Temperament influences meat quality in two ways, firstly, highly excitable animals are more stressed and therefore will have lower glycogen reserves on slaughter resulting in higher pH_u and concomitant meat quality defects. Secondly, such animals are more prone to injure themselves during handling and transport resulting in increased bruising which leads to economic losses for the beef industry as well as indicating poor animal welfare.

2.8 Conclusion

Namibia is a net exporter of red meat which forces it to adhere to stringent import legislation especially in the case of the European Union (EU). Furthermore, the fact that modern consumers take an active interest not only in the quality of their foodstuff but also in its origin, animal welfare during its production and the impact its production has on the environment, forces the Namibian beef industry to address these questions. However, very little scientific data exists that describes these activities in Namibia. The objective of the current study is therefore to determine the current state of the Namibia beef industry in terms of animal welfare issues with an emphasis on on-farm activities, transport and lairage. A second objective was to attempt to quantify the effect of breed type of (older) animals on their meat quality.

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Chapter 3

Description of the current Namibian beef industry and farming practices

Abstract

This study describes the Namibian beef industry in relation to its structure, farming practices and transportation of animals to slaughter. Beef production takes place in extensive management operations which are either privately owned or communally grazed, state owned rangeland. Two main beef production systems are found in Namibia namely weaner production and steer production although a small number of animals are finished in feedlots. As a net exporter of meat Namibia has to comply with stringent import legislation of its trading partners which resulted in the introduction of the Farm Assured Namibian Meat scheme (FAN Meat) in 1999. The introduction of this traceability system resulted in increased on-farm handling prior to transportation. The various handling interventions are described. Livestock transport is done by either transport companies or private individuals owning a truck and is the least structured part of the Namibian livestock industry. All animals slaughtered at export abattoirs are subjected to a veterinary inspection and an overnight lairage period before slaughter.

3.1 Introduction

The Namibian Agricultural Sector is the 3rd biggest producer of export goods in the country and the biggest employer of all the different governmental sectors (Horsthemke, 2008). The main export goods produced are meat and table grapes of which meat is the biggest contributor to agricultural gross domestic product (GDP) (Horsthemke, 2008). Meat is exported mainly to South Africa and the European Union. In terms of beef, a total of 9,845 tons (five year average 2004-2008) of chilled and frozen de-boned cuts were exported to overseas markets whereas 10,961 tons (five year average 2004-2008) were exported to South Africa. Live export of cattle over the past five years averages at 34,930 tons, while 12,318 tons of beef were sold locally. These figures only represent animals slaughtered at abattoirs (Personal communication Schutz, 2009).

As a net exporter of meat Namibia has to adhere to international market demands and import legislations. A key aspect of these systems is the development and implementation of a traceability system – such a system called the Farm Assured Namibian Meat Scheme (FAN Meat), which traces the animal from birth to slaughter, was implemented in 2000 (Smith, Pendell, Tatum, Belk & Sofos 2008).

Current day consumers take a more informed approach to the origin of their foodstuff and this has led to an increase in animal welfare awareness which has circled back to the producers forcing the industry participants to incorporate animal welfare issues into the production chains. Although the markets for Namibian beef (mainly retailers in South Africa) demand scientific proof of good handling and welfare practises, very little such information is documented and available.

This study was aimed to determine the animal welfare situation and beef quality in the Namibian beef industry and this chapter describes the present day Namibian farming practices, handling, transport and lairage situation as observed.

3.2 Material and Methods

For this investigation a total of 41 variables related to pre-transport, transport and lairage were recorded over a two month period from April to May 2008. The variables collected include external, physical and psychological factors which affect welfare either directly or indirectly. The data was recorded for 178 consignments delivered to the Windhoek export abattoir from 128 different producers.

Questionnaires were used to collect data on place of origin of animal as well as conditions of transport, while surveys were done during lairage periods (Addenda A (i-iv)). The amount of handling prior to transport, distance and duration of journeys and lairage treatments were recorded per consignment.

Telephone interviews were conducted with individual producers, recording pre-transport handling and general management routines animals were exposed to (Addendum A (i)). Truck drivers were interviewed on arrival at the abattoir, relating to journey times and transit events (Addendum A (ii)). In lairage, observations were conducted as the animals were off-loaded, describing the off-loading as well as the condition of the animals (Addendum A (iii)). Over the lairage period further observations were made regarding animal behaviour (Addendum A (iv)). Average daily temperatures were recorded in lairage and described *en route* by the truck drivers for individual journeys.

All cattle were slaughtered at the main commercial abattoir in Windhoek (Namibia). Upon arrival at the slaughterhouse the animals were penned in lairage by consignment. Where truck loads were too large the groups were randomly divided between two lairage pens. As it was not possible to pen animals according to their place on the truck or trailer of a transporter, the stocking densities in kg/m^2 (see Table 3.2) were calculated by combining the surface areas of truck and trailer stock-crates into one and calculating the stocking density over the whole area. The same principle was applied when calculating stocking densities in lairage, when groups were allocated to two pens (see Table 3.2). Where stocking densities were calculated in m^2/animal this was done for truck and trailer individually as well as per pen.

Furthermore, informal interviews with different people working in the industry were used to describe farming practices, feedlot management and lairage practices.

Summary Statistics and One-way Frequencies were done on the collected data using SAS Enterprise Guide 3.0 (2004). Where applicable historical data from different sources was consulted to describe specific circumstances.

3.3 Results and Discussion

3.3.1 Namibian Farming Practices

Namibia is a semi-arid country where approximately 70% of the surface area is classed as savannah. Of its total surface area of 824 300 km², about 70 million hectares are suited for agriculture of which 52% is utilised by cattle farmers and 33% by small stock farmers, while the rest is mostly used for hunting of game species and tourism (Figure 3.1 Namibian land utilization) (Sherbourne, 2008).

Only 1% of the land is arable. Namibian beef is mostly produced from extensive farming operations (referred to as farms) which can range in size from 5 000 hectare to more than 20 000 hectare of semi-arid bush veldt in the commercial areas to collectively utilized rangeland in the communal areas. Most areas are classed as Sweet veldt which Scott (1947) defined as "veldt which remains palatable and nutritious when mature". The nutritional value of the grass depends on the soil type and differs between areas. Central Namibia is mainly covered by acacia tree and shrub savannah dominated by grasslands, acacia bush and Camel thorn trees (Figure 3.2 Namibian biomes) (Sherbourne, 2008).

Towards the north-east, rainfall increases and the vegetation turn into a broad-leafed tree and shrub savannah where Mopane trees dominate the landscape. The southern parts are very arid, referred to as the Nama Karoo, which is more suitable to small stock farming than beef production. The rainy season can be divided into a short rainy season from October to December and a long rainy season from January to April. Total annual rainfall ranges from 0 to more than 600 mm (Figure 3.3 Namibian annual rainfall zones). For most parts the veldt will be green and nutritive rich in the months of January to April after which it dries out (Sherbourne, 2008).

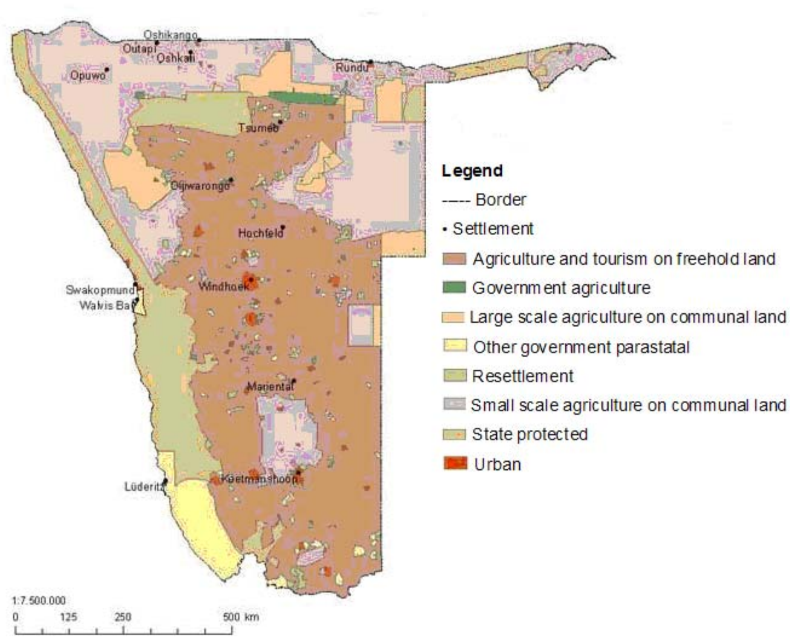

Figure 3.1 Land utilization in Namibia (Anonymous, 2002a)

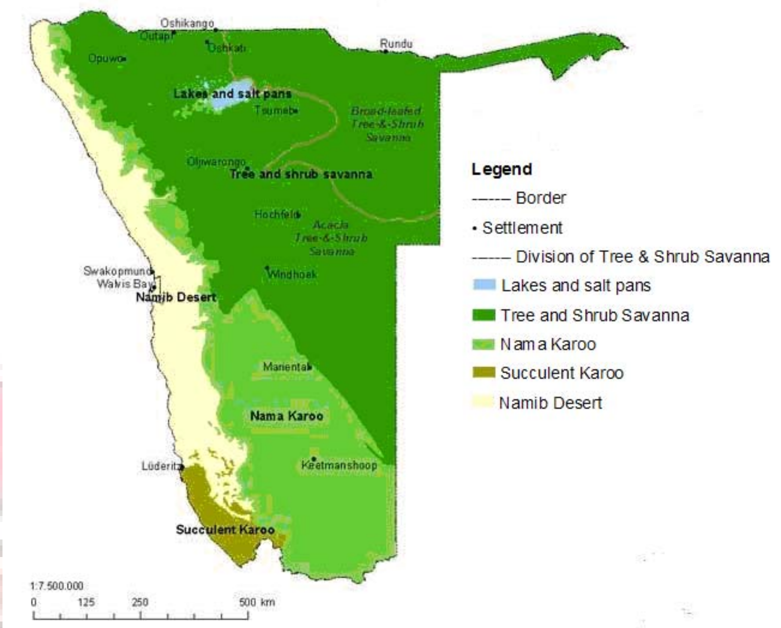

Figure 3.2 Namibian biomes (Anonymous, 2002a)

Namibia is divided into 13 governmental regions (similar to provinces) (Figure 3.4 Governmental regions and VCF). The main regions producing beef for export purposes are Khomas, Omaheke and Otjozondjupa (Table 3.1) (Mushendami, Biwa, & Gaomab, 2008). Only one area covered during the trial data collection warranted special notice; the Khomas Hochland, a very mountainous area which lies directly west of Windhoek. Animals transported in these parts had to cope with very rugged and winding road conditions.

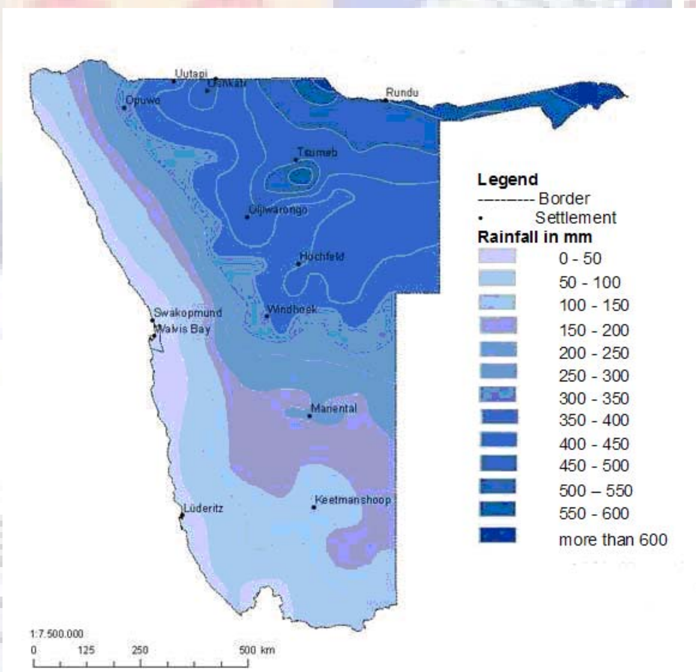

Figure 3.3 Annual rainfall zones (Anonymous, 2002a)

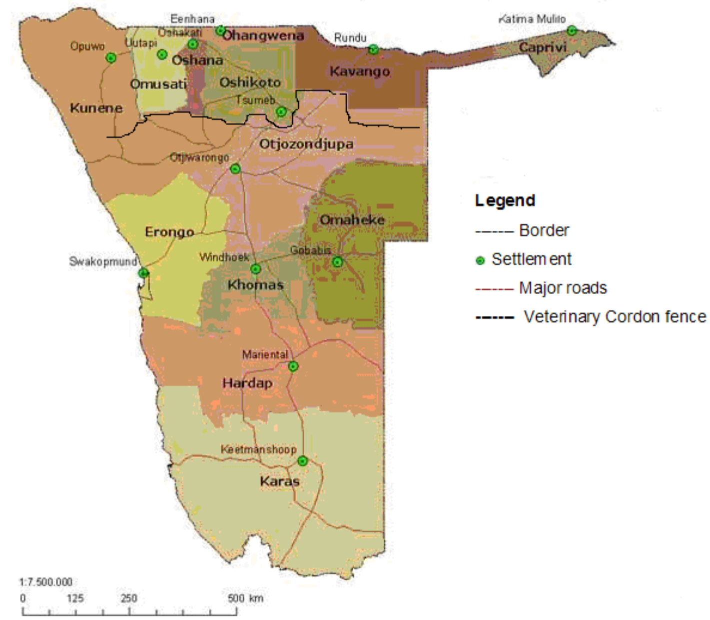

Figure 3.4 Governmental regions and VCF (Anonymous, 2002a)

Land tenure in Namibia can be divided into three broad categories, 44% of the total land area is made up of commercial farms owned by individuals who hold title to the land (9 100 registered farmers), 41% is allocated to communal tenure farms (communal land) operated by family units on land to which they have user rights but no title (66 000 registered farmers), while the remaining 15% of the land area is state owned and includes conservation areas (Sweet, 1998) (Figure 3.5 Namibian land control).

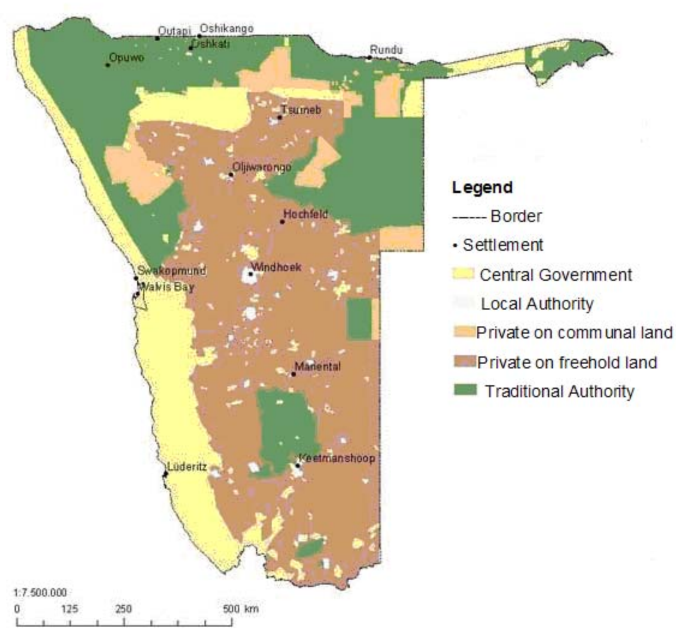

Figure 3.5 Control over land (Anonymous, 2002a)

Furthermore, Namibia is divided into two distinct animal disease zones by means of a Veterinary Cordon Fence (VCF), which runs from East to West along the southern borders of the Northern Communal Areas (Figure 3.4). The area south of the VCF is classed as “Foot and Mouth Disease” (FMD) free while the northern areas are not. This means that any marketing of livestock in the Northern Communal Areas (Omusati; Oshana; Oshikoto; Ohangwena; Kavango; Caprivi and parts of the Kunene and Otjizondjupa regions; Figure 3.4) is restricted to either slaughter for local consumption or slaughter at export abattoirs under strict quarantine requirements (Sherbourne, 2008). The commercial farmers as well as the Southern Communal Areas can market their cattle freely.

The Namibian National cattle herd comprises about 2.4 million heads of which about 750 000 are found on commercial farms, 350 000 in the Southern Communal Areas and 1.28 million in the Northern Communal Areas (Anonymous, 2006; Figure 3.6 Carrying capacity of the land & Figure 3.7 Cattle densities across Namibia).

The commercial areas are divided into fenced farms which are mostly subdivided into a number of paddocks, with artificial water points, through which some form of rotational grazing is normally practiced. In the communal areas fencing is not permitted by law and herding is still practiced in large areas. The stocking densities on commercial farm land are more conservative compared to those in the communal areas. Stock numbers tend to be less evenly distributed in the communal areas where high concentrations of people and livestock are often found near to permanent water while other areas remain under-utilised due to lack of water (Sweet, 1998). In most areas of Namibia water is supplied by ephemeral rivers and groundwater while in some areas surface dams are utilised. The only perennial rivers, the Kunene, Okavango, Zambezi, and Kwando are found in the north on parts of the borders with Angola, Botswana, Zambia, and Zimbabwe and in the south the Orange on the border with South Africa.

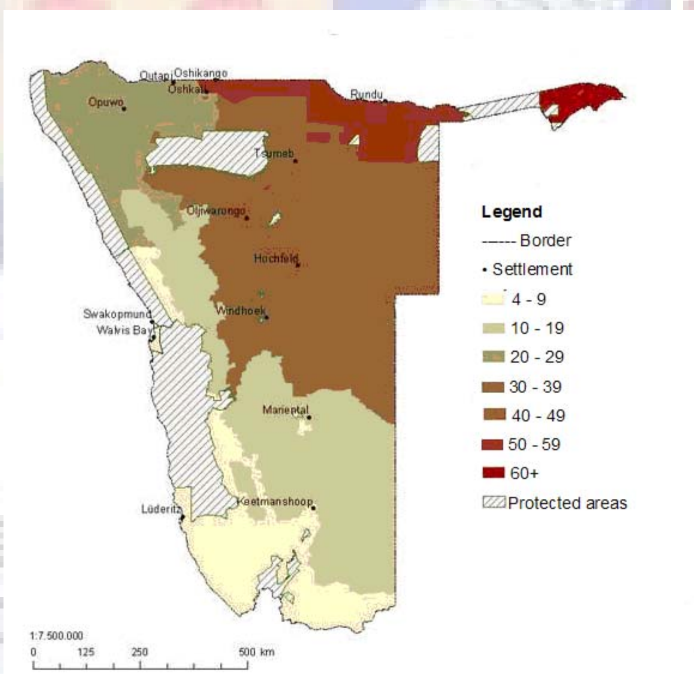

Figure 3.6 Namibian carrying capacities (Anonymous, 2002a)

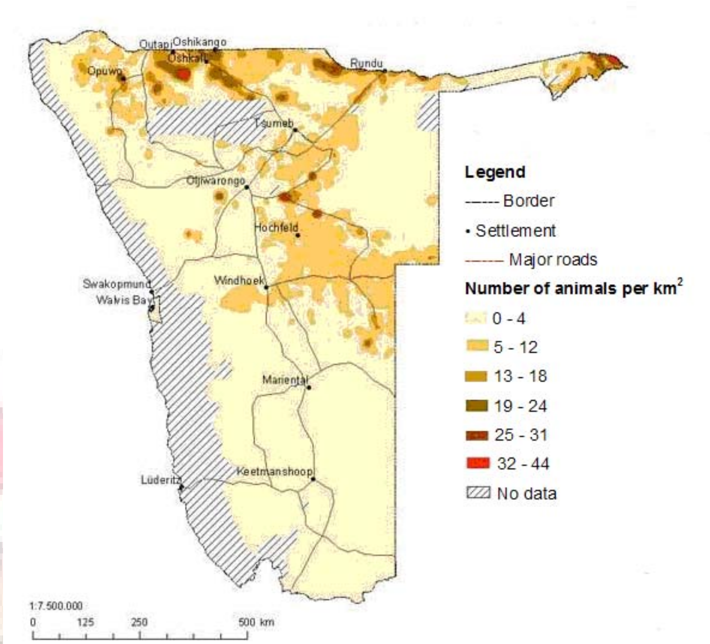

Figure 3.7 Namibian cattle densities (Anonymous, 2002a)

There are two main beef production systems found in Namibia; weaner production and steer production although a small number of animals are finished in feedlots. The choice between the two different systems depends on a number of factors including profitability, climate, fodder flow, market access, efficiency of production, size and development of farm, as well as personal preferences. One of the main differences between the systems, except for age at marketing, lies in the number of breeding females in the herd. In general weaner producing enterprises can run more cows (60%) as they do not have to feed the off-spring after weaning while steer producers have to feed the off-spring up to three years of age thus their breeding females represent about 40% of the herd. It should however be emphasised that both systems are extensive production systems and except for those animals finished off in feedlots most animals slaughtered at the export abattoirs in Namibia are free-range animals.

Approximately 156 000 head of cattle (6 year average) are exported live to South Africa yearly (Anonymous, 2009). Of this number more than 96% are weaners, calves and stores (also referred to as long yearling) sold to feedlot enterprises. This market depends a lot on factors such as feed costs and fuel prices and weaner prices vary accordingly. The years preceding 2005 saw below average rainfall seasons in South Africa decreasing local availability of weaners. This combined with low maize prices which prompted increased private feedloting in South Africa saw live exports to South Africa reached an all time high in 2005. In the following years an increase in maize price as well as the increase in fuel prices led to a decrease in demand for feedlot animals from Namibia. In 2008 a good rainy season enabled farmers in Namibia to raise weaners locally and this coupled with increased producer prices paid by local export abattoirs as well as local financing initiatives enabling farmers to turn to steer production caused a drastic drop in total marketing in 2008 (Anonymous, 2009).

The amount of handling free range animals receive during their life depends on the management system applied on individual farms but there are certain aspects which are common on all farms. This includes the prescribed yearly inoculation of anthrax of all animals and brucellosis for all heifers before ten months of age (Anonymous, 2005), and hot iron branding of all cattle at weaning (approx. 8 months old) in accordance with the Namibian Stock-brand Act 24 of 1995 (Anonymous, 1995). Therefore it can be assumed that all cattle are handled at least once a year and questionnaires done in connection with this project indicate that 75% of the farmers handle their animals more than twice a year (Table 3.1). Other handling procedures may include vaccination against other diseases i.e. Rabies, Blackquarter *(Clostridium chauvoei)*, Botulism (*Clostridium botulinum* Type C and D), trace mineral supplementation, dehorning, weighing, pregnancy testing, dipping and regrouping. Also due to specific veldt-management practices the animals could constantly be rotated through various paddock systems and most animals receive a mineral lick throughout the year supplementing the short comings of the natural veldt. During the driest months of the year farmers from certain areas in Namibia will add urea to the mineral lick as an additional nitrogen source to the dry veldt forage. These licks are distributed on a regular basis which should accustom the animals to vehicles and humans.

Most farming operations in Namibia use crossbred animals for beef production. Of the four main breeds recorded in this investigation the Simbrah breed was the most commonly documented breed (29%) in all questioned farming operations, followed by the Bonsmara breed (25.5%), the Brahman (13%) and the Simmental (5%) (Table 3.1). Other breeds reported include the Afrikaner, Beefmaster, Limousine, Nguni and Santa Gertrudis.

For most commercial farms in Namibia the animals that are ready to be marketed run in larger herds consisting of animals of different ages. Before transport they are regrouped in the sense that the group for slaughter is a fraction of the original herd. This does not strictly account as mixing but it can still cause stress to the animals, as a new dominance hierarchy needs to be established. Animals sourced from the communal areas are often mixed prior to transport as different producers share one truck. The animals will enter the lairage as one consignment and will therefore be penned together. During transport social interactions will be few as animals will be occupied maintaining their balance as long as the truck is moving. In lairage this will change and social interactions like head budding and riding will increase as new hierarchies are established (McVeigh & Tarrant, 1983; Tarrant & Grandin, 2000). This can lead to increased bruising especially when horned animals are in these groups.

The time of mustering (round up) on farm before transport depends on the size of the operation and can start up to 48 hours prior to loading with the mean lying at 17 hours before transport (Table 3.2). In most cases the animals will have access to water and in some cases to feed during this time. During the trial the amount of soiling on the trucks were recorded on arrival at the abattoir; 64% were little soiled, 31% were moderately soiled while 5% were excessively soiled (Table 3.3). These findings indicate that most animals were off feed for some time prior to transport. Especially the animals coming from the Khomas Hochland area (a mountainous area lying west of Windhoek) were fasted for some time prior to transport in order to prevent excessive soiling which could jeopardize the animals' foothold during the journey (interviews with producers from that region).

Table 3.1 Frequencies for the categorical variables on background and production aspects of free-range cattle

Item	Meaning	Total Observations	N	Frequencies (%)
District of Production		152		
	Hardap		2	1.3
	Karas		1	0.7
	Khomas		82	53.6
	Omaheke		64	41.8
	Otjozondjupa		3	2.0
Main Breed (per producer)		153		
	Bonsmara		39	25.5
	Brahman		20	13.1
	Simbrah		44	28.8
	Simmental		8	5.2
	Other		42	27.5
Amount of handling animals receive per year		152		
	Once		12	7.9
	Twice		26	17.1
	More than twice		114	75.0
Loading time on farm		164		
	< 15min		43	26.2
	15 -30 min		111	67.7
	> 30 min		10	6.1
Loading facilities on farm		164		
	Excellent		62	37.8
	Good		101	61.6
	Other		1	0.6
Use of electric goad		164		
	Yes		78	47.6
	No		86	52.4
Activities done prior to transport				
Insertion of ear tags		153		
	Yes		93	60.8
	No		60	39.2
Branding		153		
	Yes		121	79.1
	No		32	20.9
Sorting		152		
	Yes		72	47.4
	No		80	52.6
Weighing		152		
	Yes		29	19.1
	No		123	80.9
Restraint used for re-branding				
Electro-immobilizer		153		
	Yes		32	20.9
	No		121	79.1
Lifting up the tail		153		
	Yes		8	5.2
	No		145	94.8
Neck clamp		153		
	Yes		81	52.9
	No		72	47.1

Once the trucks arrive, loading on farm generally takes between 15 and 30 minutes via loading ramps which have concrete slopes and iron railings. During the trial period the truck drivers were asked to rank the loading facilities on farm considering the fact that they are able to compare different facilities from different farms. Most loading facilities on farm were described as excellent (38%) or good (62%). Electric-goads are used in about half of all loading operations (Table 3.1).

The implementation of the FAN Meat traceability system caused an increase in handling of stock before marketing similar to the implementation of cattle passports in EU (Gregory, 2008). In the period the data was collected individual animals receive a single barcode ear-tag which had to be noted down in a departure book and this form had to accompany the general animal movement permit when the animals were transported. The common practice amongst the farmers is to insert the tags shortly before transport which meant that all animals were handled through a raceway at least once before transport. Those animals already fitted with their ear-tags were also handled through a race in order to record the numbers of the animals on the departure forms. Since the end of the trial, new legislation, which took effect in August 2008, requires that the tags must be inserted latest when the animals are weaned. Another change to the tagging system is currently being implemented where animals will receive two tags, one a bar-code tag readable from a distance and one electronic RFID tag (personal communications: Dr Thalwitzer 2009). This serves as insurance for lost tags which under the current system are difficult to replace with the original number. The same departure forms will still have to be completed and thus animals will still have to be handled through a race before transport.

Furthermore due to the Namibian Stock Brands Act 24 of 1995 it is requested that all stock brands have to be legible from a five meter distance. As most animals slaughtered in Namibia are more than two years old their brands are not readily legible from that distance, especially in animals with a woollier coat and this has resulted in an increased number of cattle being re-branded before slaughter. This brand is a hair brand only, i.e. it should not disrupt/damage the skin. However, re-branding animals at two years and older, makes it more difficult to physically restrain them. This is mostly achieved in a race by either using an electrical immobilizer, a neck clamp or by bending up/lifting the tail of the animal. Eighty percent of all producers questioned during the trail re-branded their animals prior to transport. Twenty six percent of them reported the use of electro-immobilisation, 7% bend/lift the tail while about 67% restrained their animals in a chute as a hair brand can be applied quite fast. The remaining 20% did not re-brand their cattle before transport. Other activities done occasionally before transport and slaughter include sorting of herds (44%) and weighing of individual animals (29%) (Table 3.1).

3.3.2 Feed-lot management practices

The main feedlot in Namibia, situated 25 km north of Windhoek, is run by the export abattoir of Namibia and its main aim is to supply a constant flow of animals through the abattoir during the times when free-range slaughter numbers are low. Animals for the feedlot are procured throughout the country south of the veterinary cordon fence. The ideal animal weighs around 300 kg (270 – 330 kg) on entrance into the feedlot and has no more than two permanent incisors (AB grade). Large frame, *B. taurus* X *B. indicus* crosses are preferred however most animals are Brahman crosses including the Simbrah as this comprises the largest breed group in Namibia (Table 3.1). The aim of the feedlot is to produce a 230 kg dressed carcass (minimum 400 kg live weight).

Animals are fed for approximately 90 days. On entrance into the feedlot the animals receive a starter diet for two weeks followed by two weeks of grower 1; four weeks on grower 2 and four weeks on a finisher diet. The main components of the feed consist of chop, bran, brewer grains, phosphate, salt, urea, oilcake and a vitamin - trace element premix. No growth promoters or antibiotics are used to improve growth during the feeding period (personal communications: von Seydlitz, 2009).

The animals are off-loaded at the feedlot and processed the following day. Processing includes endo- and ecto-parasite control; inoculation; branding; insertion of RFID-tags; weighing and classification. Two weeks later the animals receive a booster immunisation. Before animals are sent to slaughter they are weighed and re-branded with the aid of electro-immobilization (personal communications: von Seydlitz, 2009).

Table 3.2 Number of observations (N), mean, standard deviation (SD), standard error (SE), minimum and maximum values for the continuous variables related to handling and transport in Namibia

Item	N	Mean	SD	SE	Minimum	Maximum
On farm handling						
Roundup on farm prior to transport (hrs)	153	17.1	11.4	0.9	0.5	48
Transport						
Truck size (m^2)	168	19.3	3.1	0.2	6.5	32.3
Trailer size (m^2)	132	20.9	2.6	0.2	6.1	24.3
m^2/Animal in truck	168	1.3	0.4	0.03	0.7	4.1
m^2/Animal on trailer	132	1.2	0.4	0.03	0.6	4.3
Stocking densities (kg/m^2)	151	397.1	91.7	7.5	77.6	694.7
Stops to inspect animals	160	0.9	0.9	0.1	0.0	9.3
Total distance transported (km)	153	153.6	88.6	7.2	20.0	480.0
Km tar road of total distance (km)	153	95.9	79.3	6.4	0.0	320.0
Km gravel road of total distance (km)	153	57.7	46.1	3.7	0.0	210.0
Duration of transport (hrs)	160	3.0	1.5	0.1	0.2	8.0
Lairage						
Lairage duration (hrs)	161	22.9	1.6	0.1	16.5	26.8
Minimum temperature (ºC)	164	13.4	2.7	0.2	8.0	16.0
Maximum temperature (ºC)	164	24.7	1.7	0.1	22.0	27.0
Size of holding pens (m^2)	281	77.0	8.7	0.5	72.6	94.1
Stocking density (m^2/animal)	280	4.4	1.9	0.1	2.4	18.2

3.3.3 Transportation

Although transportation is an integral part of livestock production it impinges on the welfare of animals as it violates the 'five freedoms'; freedom from fear and distress; freedom to express normal behaviour; freedom from hunger and thirst; freedom from discomfort; and freedom from pain and injury (Uetake, Ishiwata, Eguchi & Tanaka, 2008). Transport removes the animal from its natural environment and exposes it to stressors such as restricted movement, vibration, motion and noise of the truck as well as heat and cold. As it was not possible to observe the actual transport process during this investigation the data represented here is based on questions posed to the truck drivers (Addendum A (ii)). The following paragraphs describes who transports livestock, the vehicles used for transport, the road conditions, distance and time of journeys, stocking densities and weather patterns and their influence on animal welfare during transport in Namibia. The data is represented in Tables 3.2 and 3.3.

Transport is the least structured part of the Namibian livestock industry. Livestock transport is done by either transport companies or private individuals owning a truck. The drivers need a normal truck driver's licence and a permit from an official government veterinarian to certify that the vehicle is equipped to transport livestock, as well as a certificate that the truck has been cleaned by an approved station between consignments.

There are no specialised livestock transporters available but most trucks are two to three axle trucks, with or without a trailer, with crates made from metal sheets. The top is mostly open, while the sides are made up of metal sheets spaced in such a way that airflow is possible while preventing any part of the animal protruding from the vehicle. The floors are made up of solid metal sheets overlain by a welded metal mesh which prevents the animals from slipping. The livestock crates of the trucks are between 6 – 22 meters in length, 2.3 – 2.6 meters wide and 1.8 – 2.0 meter high. The length of the trailer crates range between 11 – 23 meters and are the same width as the trucks. The doors range between 1.4 – 1.7 meters in width at the same height as the truck/trailer. On very few trucks were the livestock crates subdivided to separate single animals or smaller groups. It should be mentioned that loading and unloading is normally done via the side doors of the trucks and trailers and not via the much wider tail gates.

In Namibia the vast majority of roads are gravel/dirt roads while the main roads transecting the country from north to south and from east to west are tar roads. The condition of the tar roads is generally very good while the condition of the dirt roads vary wildly. Especially during the rainy season dirt roads can become difficult to navigate. Most roads are relatively flat, except for those coming from the Khomas Hochland area lying west of Windhoek. When coming into Windhoek from the east the last 20 km before the capital are very curvy with a number of sharp bends. Road conditions influence animal welfare in two ways; firstly winding and rugged conditions will increase the number of driving events like breaking, cornering and gear shifting which forces animals to counteract vehicle movement in order to retain balance and are therefore more taxing. Secondly, poor road conditions force drivers to slow down thus increasing total journey times which further exhausts animals.

Table 3.3 Categorical data on aspects pertaining to the transport of cattle to the abattoir in Namibia

Item	Meaning	Total Observations	N	Frequencies (%)
Road condition		153		
	Flat		108	70.6
	Mountainous		45	29.4
Total distance travelled (km)		153		
	< 50		7	4.6
	50 -150		81	52.9
	151 - 250		45	29.4
	> 250		20	13.1
Duration of transport (hrs)		160		
	< 1		2	1.3
	1 - 3		99	61.9
	> 3		59	36.9
Number of stops/hour transported		160		
	none		32	20.0
	< 2		52	32.5
	> 2		76	47.5
Delays during transport		164		
	Yes		3	1.8
	No		161	98.2
Stocking density				
Truck (m^2/animal)		168		
	< 1		9	5.4
	1 - 1.6		144	85.7
	> 1.6		15	8.9
Trailer (m^2/animal)		132		
	< 1		5	3.8
	1 - 1.6		118	89.4
	> 1.6		9	6.8
Visual appraisal of stocking density		164		
	Crowded		5	3.1
	Comfortable		117	71.3
	Spacey		42	25.6
Animals lying down on transit		164		
	Yes		25	15.2
	No		139	84.8
Amount of soiling on truck		163		
	Little		109	66.9
	Moderate		46	28.2
	Excessive		8	4.9

The actual distances covered during transport are less important than road condition and actual journey time in terms of animal welfare issues (Grandin & Gallo, 2007). The average distance animals were transported during this trial can be summarised as 154 ± 89 km (Table 3.2) where the longest transport covered 480 km. If the distances are broken down into groups 53% of the trucks travelled between 50 and 150 km; 29% between 151 and 250 km; while 13% drove in access of 250 km. Those trucks travelling less than 50 km from farm to abattoir represent 5% of all recorded journeys. The region in Namibia which will travel more than 600 km to Windhoek is the Karas region in the far south of Namibia (Figure 3.5). However Karas is predominately a small stock farming area and very few consignments of cattle are shipped from that area. Compared with international transport distances the distances covered in Namibia are relatively short. It should however be mentioned that most producers from the Otjizonjupa region (Figure 3.5) slaughter their animals at the export abattoir in Okahandja, a town 80 km north of Windhoek, and that the distances covered in these areas are longer than those in the central areas. The distances recorded were further broken down into km travelled on tar and on gravel roads. The mean km travelled on tar is 96 km while the mean for gravel roads is 58 (Table 3.2).

Although there was no difference in bruising when consignments from the Khomas Hochland were compared with those from the rest of the country it became clear that the travelling speed of the trucks varied; with those from the Khomas Hochland travelling at an average speed of 40 km/h while the rest had an average speed of 60 km/h. It should also be mentioned that most roads in the Khomas Hochland area are dirt roads and this further slowed down journeys.

Table 3.2 represents the mean journey times at 3.0 hours with the shortest journey lasting 0.5 hr and the longest 8 hours. From Table 3.3 it becomes clear that 62% of all recorded trucks travelled between one and three hours, while less than 2% needed less than an hour to travel to Windhoek and 37% travelled in excess of 3 hours. In these calculations the trucks transporting the feedlot animals are not included. As the feedlot lies only 25 km outside of Windhoek the average journey time from feedlot to abattoir was 0.75 hours.

In 25% of the recorded transports, drivers reported that animals lay down during the journey. In general electric goads are used to raise lying animals. To prevent excessive bruising and pain or even death during shipment the new FAN Meat guidelines (personal communications: Dr Thalwitzer 2009) stipulates that drivers should inspect the animals 30 minutes after commencing the journey and after that at least every 2-3 hours. The number of stops recorded during the trial was between 0 and 10 times for individual journeys. The mean number of stops per hour was 0.92 ± 0.95 (Table 3.2). The old FAN Meat Manual (Anonymous, 2002b, still applicable during the time of the investigation) recommended a stop per hour which was not fulfilled. From the categorised data in Table 3.3 it can be seen that in 20% of the transports the drivers did not inspect their consignments at all during the course of the journey. The problem arising from this negligence is deaths during transport especially when coupled with higher loading densities as the downed animals are unable to get up again and can be trampled to death or are bruised excessively. Although no deaths were recorded during the two months of this investigation, eight emergency slaughters were noted, i.e. that animals were in such poor condition on arrival at the abattoir that they had to be euthanized directly. All emergency slaughters involved older cows (8 teeth), which had weak conditions at the onset of the journey and suffered additionally because they went down during transport and got trampled on by the other animals in the consignment.

During the trial period only three trucks reported delays and all were due to truck break downs (Table 3.3). Although the bruising recorded for these specific journeys was similar to those recorded for the rest of the consignments, stationary trucks represent an animal welfare problem as heat builds up fast once the ventilation due to movement ceases. It also leads to increased social interactions which potentially lead to increased bruising.

The stocking densities were calculated on a m^2/animal basis (Table 3.3) for truck and trailer individually and on a kg/m^2 (Table 3.2) basis for the combined areas of truck and trailer as it was not possible to pen and slaughter animals according to their place on the truck or trailer. Stocking densities were further visually appraised as trucks arrived in lairage. The visual appraisal indicated that most producers and/or drivers load according to animal numbers and not so much according to weights. The revised FAN Meat guidelines new loading density recommendations are given in Table 3.4. The new recommendations are based on a kg/m^2 basis as opposed to the original space allowances described in the FAN Meat Manual (Anonymous, 2002b) given in m^2/animal. Both ways of measuring space allowances are acceptable, however, measuring space allowances in kg/m^2 is more suitable in terms of animal welfare considerations as this measurement is more considerate of the different frame sizes mature cattle can exhibit. In the case of m^2/animal this does not allow for different frame sizes between breeds. Both of the possibilities do not consider horned animals and space allowances should further be adjusted where horned animals are transported (Grandin, 1981).

Loading densities recorded in this trial ranged between 78 kg/m^2 up to 695 kg/m^2 (Table 3.2); where 11% were <300 kg/m^2, 83% between 300–500 kg/m^2 and 6% >500 kg/m^2. Of all the trucks monitored during this investigation 64% had loading densities in compliance with the new FAN Meat guidelines. Of the 36% that had smaller space allowances than the guidelines require, 85% of them had animals with an average weight >450 kg. Six trucks had loading densities exceeding 600 kg/m^2. Tarrant *et al.* (1988; 1992) indicates that loading densities exceeding 600 kg/m^2 are detrimental to the welfare of the animals, however when inspecting the bruising of the six trucks in this investigation no significant differences in bruising can be seen. In fact, three of these trucks had a bruising score of zero.

Table 3.4 Space allowances as recommended by the revised FAN Meat guidelines (personal communications: Dr Thalwitzer 2009)

Weight (kg)	Loading densities (m^2)
< 250	0.5 - 0.6
250	0.77
300	0.86
350	0.98
400	1.05
450	1.13
500	1.23
550	1.34
600	1.47
650	1.63

As the data collection was done at the end of the rainy season the weather conditions during transport were mostly dry and hot (82%) and only on 18% of the journeys were the conditions dry and cold. The mean for minimum and maximum temperatures on the day of transport and the night in lairage are given in Table 3.2.

3.3.4 Lairage

The aim of holding animals in lairage prior to slaughter is to allow them to rest and recover from the transport. However lairage poses a novel situation and it is more likely that the lairage experience further increases the stress for most animals (Ferguson & Warner, 2008). This is especially true for animals with excitable temperaments and also due to the fact that most animals delivered to the lairage in Windhoek are extensively raised animals they will most likely be more stressed by the confinement of the lairage environment.

In order to reduce the stress factors for penned animals the lairage facility should ideally be placed at a quiet part of the slaughter plant (Eldridge, Warner, Winfield & Vowels, 1989) while still making it easily accessible for arriving trucks. Movement pass resting animals should be restricted to an absolute minimum and noise levels reduced. At the abattoir in Windhoek the lairage facility for cattle is well placed for off-loading and a solid wall prevents animals from seeing passing traffic on the street leading to the slaughter plant. Except for the people working in lairage little movement takes place pass the holding pens. Table 3.5 summarizes the categorical data collected on management, processing and handling procedures recorded in lairage during the trial period.

Although no specific stipulations are made in the FAN Meat guidelines (Anonymous, 2002b) in terms of lairage duration, an overnight lairage period is common practice at the export abattoir. Animals spend an average of 23 ± 1.6 hr in the holding pens before slaughter (Table 3.2). The reason given for this overnight lairage period is that animals need some time to rest and recover after transport (personal communications: Dr Thalwitzer 2009). This view is however questioned as researchers have shown that cattle take longer than 24 hours to recover from the stressors of transport (especially in terms of glycogen repletion, McVeigh & Tarrant, 1982).

The lairage facility at the abattoir is designed around a single walkway which leads from the off-loading ramp to the holding pens (Addendum B). The holding pens are built at a 90º angle to the walkway with gates opening into the walkway thereby creating barriers which prevent animals passing by their designated pens. There are two different sized holding pens; the smaller ones measure 72.6 m^2 and the larger ones 94.1 m^2 (Table 3.5). The flooring in the holding pens and walkway are made of concrete with deep groves which prevent animals from losing their footing as well as drainage channels on the sides that drain faeces and excess water during cleaning procedures. On the opposite side to the walkway water troughs are situated which are operated manually. Hay distributors are provided in each pen and are used in the case of unexpected, extended lairage times, for example when the slaughter line is stopped or when calves are born in lairage. Half of the pen is covered by corrugated iron roof providing shade and protection from the elements.

Table 3.5 Categorical data pertaining to management, processing and handling in lairage

Item	Meaning	Total Observations	N	Frequencies (%)
Animals lying on arrival		164		
	None		149	90.9
	≥ 1		15	9.2
Animals slipping on disembarking		164		
	None		108	65.9
	1 – 3		43	26.2
	> 3		13	7.9
Size of holding pens (m^2)		281		
	72.58		224	79.7
	94.12		57	20.3
Stocking density (m^2/animal)		280		
	< 3		30	10.7
	3 – 6		227	81.1
	> 6		23	8.2
Gender groupings/consignments		162		
	Cows only		23	14.2
	Steers only		46	28.4
	Cows & Steers		43	26.5
	Cows & Bulls		10	6.2
	Cows; Steers & Bulls		28	17.3
	Steers & Bulls		12	7.4

Animals have to be off-loaded before 18:00 hrs the night before they are slaughtered. Under the general lairage management procedures the lairage pens are filled from the front (pens farthest from off-loading ramp) to the back and emptied in the opposite direction in the order the trucks arrive. In the case of private slaughters (slaughters for other companies) these animals are the first to be slaughtered the next morning as they are kept in separate chillers and thus to make the process flow easier they are slaughtered as one group. No matter when these animals were off-loaded the previous day or where they are penned in lairage they are the first group to leave the lairage, which may mean altered emptying patterns. This practice might lead to the disturbance of those animals whose pens are passed by on the way to the slaughter facility (Eldridge *et al.*, 1989). Also often new consignments arriving today have to pass by those herds which still await slaughter exciting the already penned animals. Another practice which causes disruptions in lairage is the cleaning of pens between consignments. Cleaning and disinfecting between consignments is necessary in order to prevent the build up and spread of micro-organisms. However observations in lairage showed that animals react badly to the washing procedure in adjacent pens and tend to bunch up in corners bumping into facility structures and each other which will lead to increased bruising.

On arrival at the abattoir the animals are off-loaded through side doors of the trucks onto a ramp which leads into the central walkway. As the animals move from the ramp into the walkway they pass through a sprinkler system which contains a dipping agent that rids animals of flies and ticks. They then pass through the walkway to their allocated holding pens. Animals are penned according to truck loads, and as mentioned above where the truck loads exceed the holding capacity of one pen the group of animals is randomly divided between two pens. Bulls, steers and female animals are penned together when these arrived on the same truck (Table 3.5).

The stocking densities recorded in lairage are given as categorized data in Table 3.5, with a mean density of 4.4 ± 1.9 m^2 per animal (Table 3.2). Space allowances in lairage per animal was 3 m^2 and more in nearly 90% of the pens. From the observations done in lairage it can be confirmed that most consignments had ample space for animals to lie down although few of the free-range animals did so readily. The feedlot animals on the other hand lay down readily after some time most probably as they found the lairage experience less of a novelty than their free-range counterparts.

In the holding pens the animals are provided with water. The water provided is recycled sewage water and contains an anti-microbial agent to reduce the incidence of *Escherichia coli.* During the trial it was observed that most animals did not readily drink water in lairage. This might be due to novel watering facilities and/or a different taste in the recycled water (Ferguson & Warner, 2008). If one compared the drinking habits from animals sourced from the feedlot and those sourced directly from farms the feedlot animals accepted the water more readily most probably as they are more accustomed to recycled water and the anti-microbial agent added.

On slaughter day the animals are slaughtered by truck load, in the order they arrived the previous day. They are driven from the lairage pen through a broad walkway to the slaughter plant. This walkway is approximately 300 m long, and on the last part before the animals enter a single file chute before the stunning box, there are partitions where the groups coming from lairage can be kept in smaller separate groups.

Part of the observations done in lairage, were to appraise the physical and psychological condition of the animals. These variables are listed in Table 3.6. The ease of handling animals during the off-loading process showed that 83% of the animals disembarked calmly while in 14.2% of the off-loading electric goads were used to get the animals to disembark. Only in 3% of all the consignments offloaded animals vocalized during the process. In about 34% of the off-loading procedures one or more animals slipped while exiting the truck or stepping onto the off-loading ramp (Table 3.5). The reason for animals slipping at these points was mostly due to soiling from trucks spilling onto the loading ramp causing the surface to become slippery. This was aggravated when animals got excited during the off-loading procedure.

The speed by which animals exit the off-loading ramp and moved to the lairage pens was noted down showing that in 81% of the consignments the animals moved calmly through the walk-way to their holding pen, while in 8% of consignments the animals ran and in 11% electric goads were used to drive the animals into the pens.

The psychological condition of the animals on off-loading was described as alert but calm in 84% of the consignments while the other 16% showed signs of nervousness and restlessness. The latter group also tended to exit the ramp at higher speeds and ran into lairage.

Table 3.6 Categorical data describing the physical and psychological condition of animals on arrival in lairage

Item	Meaning	Total Observations	N	Frequencies (%)
Way animals disembarked		162		
	Calmly		134	82.7
	Prodded with electric goad		23	14.2
	Vocalized		5	3.1
Way animals moved to holding pens		158		
	Calm		128	81.0
	Ran		13	8.2
	Electric goad		17	10.8
Psychological appearance		164		
	Alert but calm		137	83.5
	Nervous and restless		27	16.5
Visual body condition		162		
	Good		10	6.2
	Good/medium		96	59.3
	Medium		45	27.8
	Medium/poor		9	5.6
	Poor		2	1.2
Horns		164		
	Yes		21	12.8
	No		143	87.2
Coat condition		163		
	Smooth & shiny		95	58.3
	Woolly		20	12.3
	Dirty & dusty		48	29.5
Hydration		164		
	Normal		146	89.0
	Stomach thin		2	1.2
	Eyes sunken		10	6.1
	Stomach thin & eyes sunken		6	3.7
Were animals recently branded		164		
	Yes		94	57.3
	No		70	42.7

During lairage observations the overall condition of the animals was described as good, good/medium, medium, medium/poor and poor. The reason for these overlapping classes lies in the fact that the animals which arrived early in the investigation period had to be compared with animals recorded later in the investigation which were exposed to the effects of the rainy season in full. Only 6% of the animals received a straight good condition score while most animals were classed good/medium (59%). About 27%

of the animals were classed as medium and 6% and 1% were classed as medium/poor and poor respectively. The presence of horns was noted in 13% of the consignments.

Other aspects compared in lairage include the appearance of the animal's coat; where a shiny coat was equated with a good condition compared to dull appearing hides indicative of poor wellbeing. In 39% of the herds the hides were described as either wooly or dirty and dusty (Table 3.6). The status of the eyes and stomach were observed as an indication of the hydration and nutritional state of the animals. The manifestation of sunken eyes can indicate dehydration and is often observed in sick animals while a sunken stomach is indicative of an empty gut i.e. hydration and nutritional status. In 10% of the consignments animals had sunken eyes and in 5.5% animals had shrunken stomachs.

3.4 Conclusion

Animal welfare problems especially stress and bruising can arise at any point of the above discussed stages of handling and transport and although the participants in the beef production chain can influence only certain stages and never the whole process it becomes clear that close cooperation between the producers, transporters and abattoirs are necessary in order to facilitate high animal welfare standards throughout the production chain. It is therefore recommended that information sessions be held where producers can be enlightened about the consequences of some of their management practices. A good opportunity may be during the training/information sessions of the new FAN Meat guidelines. As it is difficult to assess stress in animals, bruising can be used as an indicator of animal welfare. The following chapter will discuss the implications of the different events of handling, transport and lairage on the amount of bruising observed at slaughter.

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Chapter 4

Causes of cattle bruising during handling and transport in Namibia

Abstract

There are numerous risks associated with transport and handling which all have the potential to cause bruising and poor welfare to animals. The variables which were identified as high risk factors and had a significant influence on the level of bruising under Namibian transport conditions include animal factors (breed type, age, sex, condition and subcutaneous fat cover), pre-transport handling (re-branding of animals), transport related risks (loading density, and animals lying down during transit) as well as lairage factors (fit of truck floor to off-loading ramp, the way animals moved to holding pen, pen size and minimum temperatures). However, no single factor could be pin pointed as the driving force behind bruise levels and the overall impression is that these risks have a cumulative effect on bruising.

The degree and age of bruises were recorded in a separate investigation at the same abattoir and results reflect that the overall incidence of bruising is very high, with the highest levels seen on the hips, around the butt and pin areas.

The results of this study indicate that in the event of animals transported to slaughter in the central areas of Namibia conditions surrounding transport are more important than distance transported or journey duration.

4.1 Introduction

Transportation is an integral part of extensive animal production and is not inherently bad or good for animal welfare. However there are numerous risks associated with transport and it is the management of these risks which determine the level of welfare animals' experience. Fisher, Colditz, Lee and Ferguson (2009) grouped these risks into three categories: (1) stress and fear due to handling, loading and the conditions and novelty of transport; (2) hydration, energy, and fatigue challenges that increase with transport duration; and (3) risks to the thermal comfort and physical integrity of the animals.

Transportation and the associated increase in handling are necessary components of the Namibian beef production chain. When considering the costs of transportation there are the direct costs of freight charges and sometimes insurance, and then there are indirect costs manifested in live weight (shrink) loss and bruising. The degree of shrinking observed in slaughter animals depends on the time period that animals are off feed and water. The degree of dehydration observed also depends on the ambient temperatures and relative humidity. In the case of mild dehydration providing animals with water in lairage will remedy the situation. Bruising on the other hand cannot be remedied before slaughter and has to be trimmed off the carcass. The losses experienced at the major Namibia export abattoirs due to bruising are represented in Table 4.1 for the years 2006 and 2007.

Table 4.1 Total bruising scores and their financial implications recorded at Meatco for the years 2006 and 2007 (Personal communications: Dr. Thalwitzer)

Year	Bruising Code	Number of cattle	Total loss (N$)
2006	0	100,809.0	0.0
	1	6,285.5	69,140.5
	2	896.5	49,307.5
	3	37.5	6,600.0
	CC	357.0	1,433,648.0
Total		**108,385.5**	**1,558,696.0**
2007	0	100,949.0	0.0
	1	6,454.5	70,999.5
	2	889.5	48,922.5
	3	23.5	4,136.0
	CC	475.0	2,118,754.0
Total		**108,791.5**	**2,242,812.0**

Bruising Code: 0 - none (no mass loss); 1 - light (0.5kg mass trimmed); 2 - medium (1 -3 kg mass trimmed); 3 - severe (3 -10 kg mass trimmed); CC - condemned (100% mass loss)

The main factors influencing bruising during handling and transport are stockman-ship, facility and vehicle design, driving style, road conditions, mixing of animals before transport or in lairage, presence of horned animals, and animal temperament (Grandin, 2007).

By definition a bruise is “an injury appearing as an area of discoloured skin on an animal body, caused by a blow or impact which ruptures underlying blood vessels” (Anonymous, 1995a). No laceration is caused on the skin and therefore blood and serum from the damaged vessels accumulate in the tissue (Hoffman et al. 1998) which leads to pain, swelling and tenderness (Blood & Studdert, 1988). In the event of handling and transport most bruising is the result of physical blows from driving instruments like sticks, projecting objects in facilities and trucks, and animals falling (Chambers, Grandin, Heinz, Srisuvan, 2004). The location, severity and appearance of bruises vary widely and all three aspects give valuable clues on the cause of the injury. The location as well as the frequency with which certain bruises appear on slaughter are indicative of specific handling or transportation events and can be utilized to determine problem areas in the transport chain (Jago, Hargreaves, Harcourt, Matthews, 1996; Grandin, 1990; 2001). The size and discolouration of a bruise can be used to determine the age of a bruise as this changes over time (Gracey & Collins, 1992).

This chapter discusses the factors identified during the current investigation as possible causes for bruising observed at the Windhoek export abattoir.

4.2 Material and Methods

A total of 42 variables related to pre-transport, transport and lairage were recorded over a two month period from April to May 2008. The data was recorded for 178 consignments delivered to the Windhoek export abattoir from 128 different producers.

Questionnaires were used to collect data on place of origin of animal as well as conditions of transport, while surveys were done during lairage periods (Addendum A). The amount of handling prior to transport, distance and duration of journeys and lairage treatments were recorded per consignment.

Telephone interviews were conducted with individual producers, recording pre-transport handling and general management routines animals were exposed to (Addendum A (i)). Truck drivers were interviewed on arrival at the abattoir, relating to journey times and transit events (Addendum A (ii)). In lairage, observations were conducted as the animals were off-loaded, describing the off-loading as well as the condition of the animals (Addendum A (iii)). Over the lairage period further observations were made regarding animal behaviour (Appendix A (iv)). Average daily temperatures were recorded in lairage and described *en route* by the truck drivers for individual journeys. All cattle were slaughtered at the main commercial abattoir in Windhoek (Namibia).

For the main investigation bruising scores as evaluated by the quality control personnel of the abattoir according to normal abattoir management procedures were used. Carcass halves receive one score based on the severity and location of bruises. This score is recorded on the slaughter floor reports which are based on individual animals and grouped according to producers. Producers delivering to the abattoir are paid for carcass weight and are insured for losses due to trimming of bruised tissue. This latter fact could lead to under representation of bruises on the cheap cuts.

In a separate investigation on the slaughter line of the same export abattoir in Windhoek the location, severity and colour of bruises were recorded independently from the quality personnel of the abattoir. Carcasses were broken down into seven distinct zones (A, B, C, D, E, H & I) and two high risk areas F and G (hips and butt/pin) as depicted in Figure 4.1 and bruises scored for left and right side, as well as the middle where applicable. Over a time period of six full slaughter days at the export abattoir in Windhoek, 50% of the carcasses were screened for bruises on any particular day.

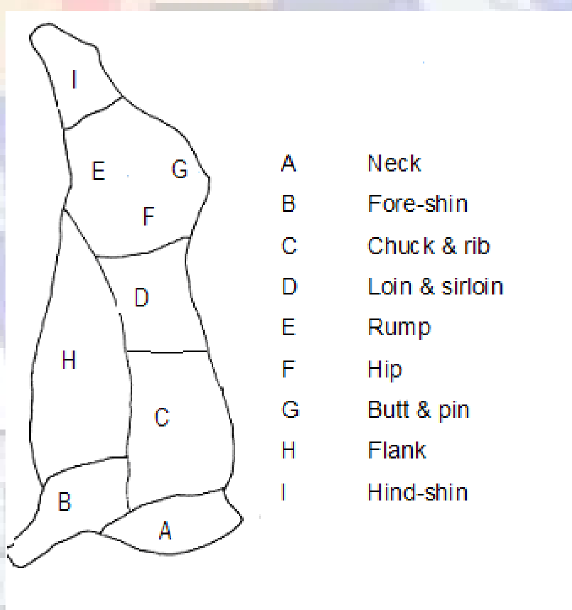

Figure 4.1 Carcass areas differentiated for bruising recordings

The severity of the bruises was determined by considering the area covered by the bruise and whether it was superficial or affected deeper lying tissues. The colour and consistency of bruises were evaluated and linked to age according to the following principles: bright, haemorrhagic red appearance (approximately 0 – 10 hours old); dark red colour (± 24 hours of age); watery consistency (24 – 38 hours of age); and rusty orange colour (> 3 days of age) (Gracey & Collins, 1992).

Statistical evaluation of the data was started with an exploratory analysis of the consignment data by running a multivariate principle component analysis on continues variables and cluster analysis on the categorical variables. This was followed by an univariate analysis calculating Spearman correlations for the scaled variables and Mann-Whitney and Kruskal-Wallis tests on the un-scaled variables (Table 4.2). Thereafter, the slaughter floor data per animal was combined with the consignment data and a logistic regression analysis was done on the combined data with bruise categories as dependent variable using generalized linear model (PROC GENMOD) of SAS, with an accumulative logit link (Table 4.3).

4.3 Results

Due to the nature of the data presented in this investigation all results will be discussed as being significant at a 90% confidence limit.

The preliminary data analysis using multivariate principle component analysis showed some associations between the variables and the percentage bruising seen in the consignments. The strongest association was found with animals slipping on disembarking where 14% of the variation was explained by the model. When reducing the number of variables in the model, lairage duration (11% variation explained by model) and time of mustering on farm (9% variation explained by the model) also showed an association with bruising.

Other associations between variables included travel speed and the amount of gravel road covered (11%); the percentage of animals lying on arrival at the abattoir and the distance of gravel travelled (10%); as well as an association between loading density and animals slipping during disembarking (9%).

In the cluster analysis of the categorical data the percentage bruising was categorized into the following four levels: A < 10%; B = 10 - 19%; C = 20 - 29%; D > 30%. Variables which associated with bruising level A were lairage duration and the longer distances covered on gravel during transport. Bruising level B was associated closely with horns while level C was grouped with total number of animals per consignment and number of animals slipping on disembarking. The highest bruise level was associated with the way animals disembarked and how many animals slipped during this process as well as the way the animals moved to their designated holding pen.

Results from the univariate analysis in terms of p-values for Spearman correlations for the continuous data and p-values of the Mann-Whitney and Kruskal-Wallis tests on categorical variables are summarized in Table 4.2. From the continuous variables only four out of 16 showed significant correlation with percentage animals bruised per consignment at a 95% confidence level while one more was included at a 90% confidence level. These variables include number of animals per truck, truck size in square meters, size of holding pens, number of animals per holding pen and minimum temperature. For the categorical data five out of 25 variables were included at a 90% confidence level. They included gender groupings transported, visual appraisal of stocking density, how animals disembarked, hydration state and horned animals.

Table 4.2 Variables associated with bruising (determined by using one-way analysis of variance by ranks and spearman correlations)

Item	**Total observations**	**Mann–Whitney U**	**Kruskal-Wallis**	**Spearman Correlation**
Physical animal factors				
Hydration	164	0.06		
Horns	164	0.04		
Transport				
Number of animals per truck	168			0.05
Truck size (m^2)	168			0.09
Gender combinations/consignments	162		0.07	
Visual appraisal of stocking density	164	0.04		
Way animals disembarked	162	0.07		
Lairage				
Size of holding pens (m^2)	281			0.01
Number of animals per holding pen	281			0.04
Minimum temperature (ºC)	164			0.03

After the preliminary analysis, the slaughter floor reports and the consignment data were combined and the final model determined by running a logistic regression on the combined data. Those variables included in the final model are presented in Table 4.3.

4.3.1 Physical Animal Factors

Breed type affected bruising ($p = 0.001$). Higher incidences of bruising were recorded for the Simmental and Brahman breed crosses when compared with the Bonsmara and Simbrah animals (Table 4.3).

The sex of the animals transported could also be associated with bruising in this investigation (Table 4.3). The levels of bruising were higher for the female animals ($p < 0.0001$) compared to males. Although overall bruising was similar between cows and heifers severe bruising was higher in cows than in heifers. Eighty three percent of the carcasses condemned for bruising were old cows (eight teeth). This was also reflected in the inclusion of dentition ($p <.0001$) as one of the variables in the final model.

The animals were visually appraised in lairage and their overall condition grouped between 'good' to 'poor'. Due to the change in season and the fact that the animals arriving at the abattoir early during the investigation did not have the chance to utilize the full advantage of the green season the groupings in condition were further subdivided into 'good/medium', 'medium' and 'medium/poor'. This visual condition could be linked to the bruising levels in these consignments (Table 4.3). Animals with a condition termed 'medium' showed higher bruise levels than any other group.

Table 4.3 Variables included in the final model determined by logistic regression analysis of the combined data

Item	DF	Chi-Square	p-value
Physical animal factors			
Breed	4	19.07	0.001
Sex	3	45.30	< 0.0001
Visual condition of animals	4	14.81	0.005
Body live mass	1	55.49	< 0.0001
Average live-weight	1	8.16	0.004
Fat code	6	14.10	0.029
On-farm handling prior to transport			
Re-branding	1	8.88	0.003
Transport			
Loading density truck (m^2/animal)	1	3.54	0.060
Animals lying down during transport	1	3.33	0.068
Lairage			
Truck door to ramp fit	2	6.08	0.048
Way animals moved to holding pens	2	9.29	0.010
Size of holding pens	1	9.34	0.002
Minimum temperature	1	12.52	< 0.0001

Body live mass of individual animals and average body mass per consignment were two more variables included in the final model (Table 4.3). Their effect on bruising seem contradictory as bruising tended to be higher in animals with lower live-weights (< 350 kg) while on the other hand bruising increased as average live-weight per consignment increased. Furthermore, the fat code assigned during carcass classification also showed a significant influence on bruising ($p < 0.05$). Animals with no subcutaneous fat (code 0) and animals with thicker subcutaneous fat layers (code 4 and 5) showed higher levels of bruising than animals with intermediate fat scores.

During lairage observations 'sunken eyes' and 'thin stomachs' were taken as an indication of state of hydration of the animals. A higher level of bruising was found in animals which appeared visibly dehydrated compared to those that did not show any visible signs of dehydration (Table 4.2).

In the course of this investigation there was no single consignment where all animals had horns but a few where some animals had horns while the great majority of consignments carried no horned animals. Although the presence of horns was not included in the final model, in the preliminary analysis consignments including horned animals showed higher levels of bruising compared with groups which did not include horned animals (Table 4.2).

4.3.2 On-farm handling prior to transport

Of all the handling variables and associated handling practice variables recorded during this investigation only re-branding of the animals prior to transport had an influence ($p < 0.05$) on the amount of bruising observed once the animals were slaughtered (Table 4.3). Re-branded animals had higher incidence and degrees of bruising compared with consignments where this additional handling before transport was not preformed.

4.3.3 Transport

From the transport variables only loading density (in m^2/animal; $p = 0.06$) and animals lying down during transit ($p = 0.068$) showed a significant association with bruising and were included in the final model (Table 4.3). Other variables showed significant influence on bruising in the exploratory data analysis and these included truck size, total number of animals per truck, gender groupings per consignments, visual condition of animals, and the way animals disembarked (Table 4.2).

The general trend observed between truck size and number of animals per truck and their influence on bruising were increased number of animals bruised as truck size and number of animals increased (Table 4.2). Whether this higher incidence of bruising was the result of truck size per se or an increased chance due to increased numbers of animals loaded could not be determined.

Stocking densities on trucks were grouped as ‘spacey’, ‘comfortable’ and ‘crowded’ by visual appraisal on arrival at the abattoir (Table 4.2). The consignments which were classed as ‘comfortable’ had a higher incidence of bruising than the other two groups. However, 71% of all recorded consignments fell into the ‘comfortable’ category while 26% were classed as ‘spacey’ and only 3% as ‘crowded’. The consignments which were classed as ‘spacey’ were delivered in small, owner driven trucks carrying very few animals. Therefore, it could not be established whether the higher level of bruising seen in the ‘comfortable’ consignments was the result of stocking density or the lower bruising recorded for the ‘spacey’ consignments the result of owners taking greater care of their animals during transport. When considering the actual loading densities (as included in the final model) calculated as square meter available per animal bruising increased as the area available per animal decreased.

Of those trucks which came in repeatedly during the investigation period truck T1T1C (consisting of a truck and a trailer) was chosen to depict the variation in bruising per consignment if the truck and driver remained the same (Figure 4.2). This variation was even higher between trucks of different size driven by different people. Figure 4.2 shows how the bruising differed between different trips. Trip 1, 4, 9 and 10 showed above average bruising. When considering the available information certain common factors appeared in all four trips namely low travel speeds, high number of stops to inspect animals, and the majority of the total distance covered were gravel roads. In trip 10 the high percentage of bruising could also result from very low stocking densities depriving individual animals of the stabilizing effect of pen mates. However, the causes for these observations could not be verified statistically and are assumptions based on available literature.

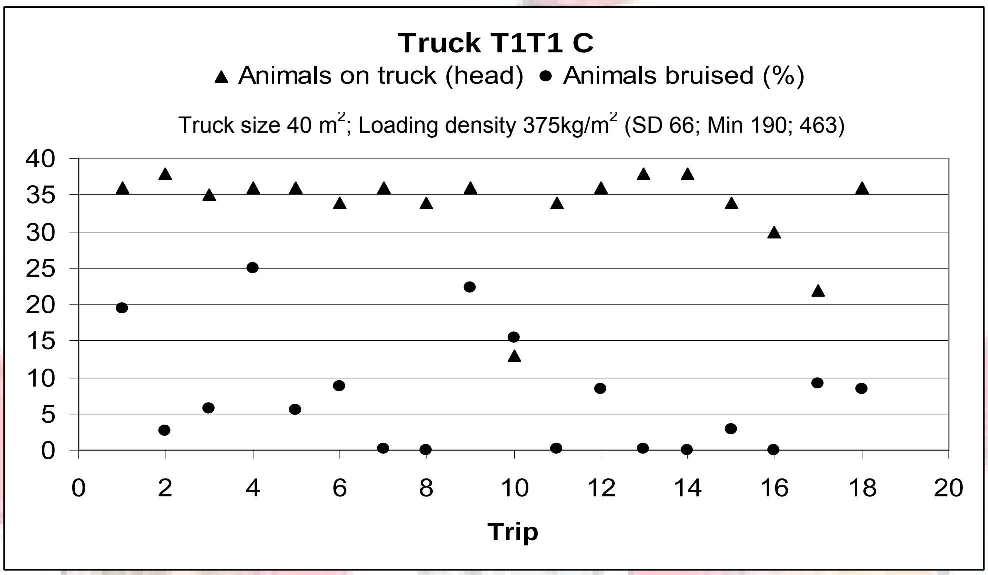

Figure 4.2 Schematic presentation of number of animals per consignment and percentage animals bruised per consignment where the same truck (T1T1 C) and driver was evaluated.

The combination of different sexes (including steers) affected bruising in this investigation. Preliminary data analysis (Table 4.2) showed that bruising was significantly higher in consignments which carried cows only compared with cows and steers, steers only, and steers and bulls. On the other hand bruising did not differ between cows only consignments, cows and bulls, and consignments that carried all three genders.

Bruising was higher in consignments where animals were reported to have lain down during transport (final model; Table 4.3) as well as in consignments where electric goads were used during off-loading (disembarking, Table 4.2). Observations in lairage showed that animals who disembarked calmly and without the persuasion of electric goads had fewer slips and falls while exiting the truck and tended to move to the holding pens at lower speeds compared with animals persuaded by electric goad to exit the truck. The latter often ran into lairage. Traumatic events like slips, falls and bumping into structures like gates and fencepost were observed to be much higher in the latter group.

4.3.4 Lairage

The lairage variables which are included in the final model are the fit between truck door and off-loading ramp ($p = 0.05$), the way animals moved through the central walk way into their designated holding pens ($p = 0.01$), the size of the holding pens ($p = 0.002$), as well as the minimum temperature recorded for the night the animals stayed in lairage (Table 4.3).

Observations on off-loading showed higher incidences of slips and falls in trucks where the truck door and the off-loading ramp were not at the same height thus forcing animals to step up or down when disembarking. This was reflected in the larger amount of bruising observed after slaughter.

Furthermore, the way animals moved to their holding pens i.e. calmly walked, ran or needed persuasion with an electric goad had an influence on the bruise levels seen. For the same reasons as described above on disembarking the truck, animals that ran into their holding pens had higher bruise scores due to traumatic events than those that walked calmly, while no difference was found between consignments driven with the aid of electric goads and animals which entered lairage at a walk without persuasion.

Pen size (Table 4.3) and number of animals per pen (Table 4.2) influenced bruising in the same way as truck size and number of animals per consignment, i.e. as the pen size increased so did the incidence of bruising and the same trend applied to number of animals per pen and bruising. Whether this increase in bruising is the result of pen size and animal numbers or a reflection of larger pen sizes holding larger numbers of animals thus increasing the chance for bruises could not be determined.

Daily minimum and maximum temperatures were recorded in lairage during the investigation period and minimum temperature ($p < 0.0001$) was linked to bruising levels (Table 4.2 & 4.3). As the minimum temperature increased from 8 to 16ºC an increased incident in bruising was observed. Maximum temperature on the other hand did not affect bruise levels.

4.3.5 Bruise location and age

The results for the observations on bruise location and colour are shown in Figure 4.3 and Table 4.4. The locations with the highest amount of bruising were the hips with 72% and 73% for the right and left side respectively. This was followed by the middle of the chuck and rib area (36%), middle of the rump area (31%), and the parts around the butt and pin area (28%) and the central back (28%). The biggest difference was observed between the right and left flank which showed 20% and 27% bruising.

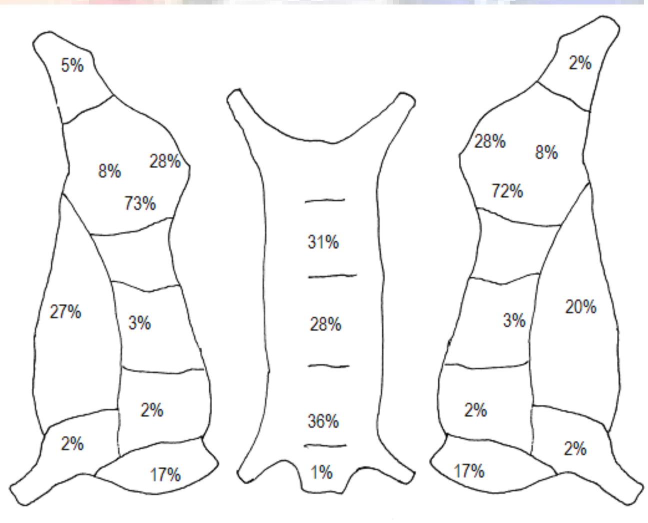

Figure 4.3 Cumulative frequency of bruising recorded for cattle (n = 1295) at different locations on the carcass.

The highest numbers of bright red bruises (indicating fresh bruises) was observed on the central rump and are assumed to be the result of the fall gate which closes the stun box. Dark red bruises were recorded on the hips, over most areas of the central back and also on the flanks. Bruises of this type on the middle chuck/rib area could be the result of animals hitting horizontal cross-bars in raceways and squeeze chutes as well as neck clamps. These bruises were especially noted in humped animals. Bruises of category C were mostly centred on the butt and pin area and on the hips and the same areas showed the highest incidence of old (category D) bruises. These may be linked to the animals being mustered and processed through raceways on farm prior to loading.

Table 4.4 Colour of bruises grouped according to carcass location and age of bruise

	Colour				
Area	**No bruise**	**A**	**B**	**C**	**D**
Neck left	83.24	0.39	9.73	4.86	1.78
Neck middle	99.38	0.08	0.39	0.08	0.08
Neck right	82.78	0.93	9.42	4.94	1.93
Fore-shin left	98.46	0.00	1.08	0.46	0.00
Fore-shin right	97.07	0.62	0.39	0.69	0.23
Chuck/Rib left	97.76	0.08	1.16	0.85	0.15
Chuck/Rib middle	63.55	1.85	20.31	13.51	0.77
Chuck/Rib right	97.76	0.15	1.39	0.62	0.08
Loin/Sirloin left	97.37	0.23	1.47	0.77	0.15
Loin/Sirloin middle	71.58	3.24	18.53	6.10	0.54
Loin/Sirloin right	96.83	0.31	2.01	0.69	0.15
Rump left	91.51	1.08	5.25	2.08	0.08
Rump middle	68.57	15.21	12.50	3.63	0.08
Rump right	91.66	1.08	4.56	2.32	0.39
Hip left	26.80	3.47	30.19	37.61	1.93
Hip right	27.72	3.40	30.12	36.91	1.85
Butt/pin left	71.51	0.15	4.48	21.85	2.01
Butt/pin right	72.36	0.08	4.48	21.31	1.78
Flank left	73.44	0.54	18.30	7.18	0.54
Flank right	80.31	0.62	12.28	6.25	0.54
Hind-shin left	94.98	1.24	3.01	0.62	0.15
Hind-shin right	97.76	0.54	1.31	0.23	0.15

A - 0-10 hrs red & haemorrhagic; B - +/- 24 hrs dark colour; C - 24 - 48 hrs watery consistency; D - > 3 days rusty orange colour (billirubin) & soapy to touch

4.4 Discussion

Two factors make the use of bruising as a welfare measurement difficult. Firstly, bruising in animals can only be measured once the animal is slaughtered. The bruise however could happen at various points in the handling and transport chain and although the age of bruises can be determined to some degree by its colour it is difficult to determine the actual event which led to the bruise. The second factor is the fact that bruising is accumulative, meaning that the animal can bump the same body part repeatedly during the course of handling and transport. This increases the severity of the bruise and makes it difficult to determine its age. The hip bruises reported in this investigation often showed this phenomenon where the extent and colour of the bruise indicated that the area was bumped repeatedly during the transportation chain.

The animal's response to the different stressors of transport and handling determines the welfare during these events. The degree of response shown by an animal to any form of environmental challenge depends on its perception of the challenge and is subsequently a result of individual differences.

4.4.1 Physical animal factors

For extensively raised animals, especially where these animals come from an environment which includes predators (diverse environment), fear is a strong motivator (Grandin, 2007) and their fright and flight reaction much more pronounced compared with animals raised in poorer environments, i.e. environments with little different stimuli. The stress response during handling also depends on the genetic differences within a breed as well as differences between breeds. Animals with flighty genetics tend to react much stronger to novel events than animals with calmer temperaments (Grandin & Deesing, 1998). Extensively reared animals are generally more flighty than animals reared in close association with humans (Grandin, 2007). Susceptibility to bruising and temperament differs between individual animals and Fordyce, Goddard, Tyler, William and Toleman (1985) concluded that this was more important than breed differences. However, Manteca and Ruiz de la Torre (1996) suggested that animals from environments with varied stimuli show a more fine tuned response to different stressors and that these animals 'get over' the fright reaction of a specific stimulus faster than animals raised in poorer environments.

Some evidence exists in literature that sex and age effects the level of bruising observed on slaughter. Jarvis, Selkirk and Cockram (1995) showed that heifers had higher bruise levels when they were completely separated from steers during handling and transport. Similar results were described by Yeh, Anderson, Jones and Shaw (1978) who found that cows bruised significantly more than steers and bulls and also that only in cows did the amount of trimming per carcass due to bruising increase with the length of the journey. This is contrary to results reported by Wythes, Kaus and Newman (1985) who reported no increase in bruising with increased transport distances. The latter findings compare to findings of this trial where no relation between distance and bruising could be established. Results from the current investigation also showed higher bruise levels in females compared to steers and bulls (Table 4.3), especially in the case of old cows. Furthermore, when considering the age (number of permanent incisors, Table 4.3) of the animals, the level of bruising differed between older (6 – 8 teeth) and younger animals, the former having a higher bruising score. Wythes and Shorthose (1991) reported that bruising was greatest in old cows and steers which also represented the heaviest animals of the group. It has been suggested that fat cover, skin and hide thickness could affect the susceptibility to bruising from impacts with a similar force (Weeks, McNally and Warriss, 2002). The current results support this statement as animals with live weights below 350 kg had more bruises while animals with no fat cover and animals with the highest fat cover showed increased levels of bruising (Table 4.3). Furthermore, the body condition of the animals in different consignments was described in lairage and animals with better condition scores showed less bruising than those with medium to poor scores (Table 4.3).

Social interaction, especially aggressive interactions between animals lead to bruising. Kenny and Tarrant (1987 a, b) monitored the physiological and behavioural responses of Friesian steers and bulls to specific events of road transport and found that simply re-penning animals in a novel environment led to a marked increase in social interactions. As the transport treatments started to overlap, i.e. novel environment, close confinement and motion of the vehicle, social interactions decreased. This observation held true for regrouped and non-mixed animals. It also emphasises the fact that unnecessary stops during short-distance transport can lead to increased bruising as animals will interact more on stationary trucks. Once the animals are off-loaded and penned at the abattoir social interactions will again increase. Blackshaw, Blackshaw and Kusano (1987) studied the behaviour of cattle at a large sale yard and found that the neck and flank area of animals were butted by other animals more often than the hindquarters. Furthermore, the same authors described that as animals were made to move they often bumped into structures of the facilities - an event which is associated with increased bruising and ascribed this to poor stockmanship and facility design. Mounting has been reported in literature to be the behaviour that most frequently results in dark, firm, dry meat (DFD), a quality defect which results in poorer colour and shelf-life of the product. This behaviour is often elicited by regrouping, mixed penning of young bulls (McVeigh & Tarrant, 1983) and oestrus in female and mixed gender groups. However, very little information has been published on mounting behaviour and its impact on bruising. Kenny and Tarrant (1987c) reported an association between bruising and mounting behaviour observed in lairage. In this investigation very little mounting behaviour was expressed in lairage and the occurrence of this behaviour could not be linked with bruising.

It is a well established fact that the presence of horns leads to increased bruising during transport (Meischke, Ramsay & Shaw, 1974; Ramsay, Meiscke & Anderson, 1976; Wythes *et al.*, 1985; Minka & Ayo, 2007). Wythes *et al*. (1985) showed that tipping horns does not reduce the incidence of bruising. This also reflected in stocking density recommendations by Grandin (1981) which stipulates that where horned animals are transported, stocking densities need to be adjusted. During this investigation all horned animals were mixed with de-horned animals and although horns did not affect bruising in the final model, preliminary results indicated that bruising was higher in groups that contained horned animals. Wythes *et al*. (1985) also failed to find a definite trend between horns and bruising.

4.4.2 On-farm handling prior to transport

In Chapter 1 the importance of handling facility design and stockmanship in connection with animal welfare was described. As no on-farm observations were done during this investigation these two factors will not be discussed here although their importance should be emphasized and were accentuated by Ferguson and Warner (2008).

Mustering (round-up) on-farm before slaughter is the start of increased handling associated with transport. In Namibia the event of mustering can start up to 48 hours prior to loading and presents the first incidence of handling before transport. This is most often followed by necessary processing practices in order to prepare the animals for the actual transport. Sorting of existing herds to identify marketable animals, separating identified animals, tagging, branding and weighing are the most common pre-transport practices reported in this investigation.

The severity of energy and hydration challenges animals are exposed to depend to a large extent on the management practices applied during pre-transport handling and the duration of the actual transport and lairage period. Food deprival often starts with mustering while water is generally provided to the animals until a few hours prior to loading and again after transport while resting in lairage. In this investigation animals that were noted in lairage with sunken eyes and stomach also had higher bruising scores. Fasting increased bruising in a study done by Dodt, Anderson and Horder (1979) that compared bruise trim in fed and unfed bulls after transport.

In Namibia the group of animals sent to slaughter often represents a fraction of a larger herd. Although the sorting of herds and separation of marketable animals does not strictly speaking count as mixing, it still disrupts the social structure and will lead to increased social interactions with the potential for bruising (Kenny & Tarrant, 1987a, b). Furthermore, where trucks are shared by different producers as is sometimes the case in communal areas, animals of different origin are mixed during transport and later also penned together in lairage. Mounting and head butting are agonistic behaviour displayed by beef cattle on regrouping and are both associated with an increased risk of bruising (Warriss, 1990). Social interactions can take place on-farm prior to transport, on stationary trucks and in lairage.

The introduction of the Namibian traceability system brought with it an increase in handling of animals directly before transport. Producers have to record individual animal identification numbers in the departure register which then has to accompany the general livestock movement permit on the truck. In order to read the individual ID numbers the animals need to be handled in a chute prior to loading.

The one handling variable which had a significant effect on bruising was re-branding ($p < 0.05$). The practice of re-branding stems from the stipulation under the Namibian Stock Brand Act that the brand be readable from a five meter distance (Anonymous, 1995b). The free-range animals marketed in Namibia are mostly older and the visibility of the brands they received on weaning (approximately 8 months of age) can be poor - especially on animals with woollier coats. Therefore re-branding animals before transport is a common practice in Namibia. Although this second brand is a hair-brand only, it is necessary to restrain the animal in order to facilitate clear brands. This is achieved in three ways, either by using an electro-immobilizer, neck-clamp or a combination of neck clamp and pushing up the tail of the animal to force immobility. Although the practice of pushing up the tail does not significantly affect bruising at a 90% confidence level there are some indications that this practice leads to increased bruising. Considering that most animals are raised extensively the close contact between animal and human in order to achieve this practice is likely to cause considerable stress to the animal as well as pain. It is assumed that the avoidance reaction of the animal will lead to increased bruising.

4.4.3 Transport

As mentioned earlier livestock transport is the least structured part of the Namibian beef producing industry and is done either by transport companies or private individuals. Very little legislation governs this branch of the industry although guidelines for livestock transporters form part of the FAN Meat Manual (Anonymous, 2002).

Contrary to findings by other authors (Minka & Ayo, 2007; Yeh *et al.,* 1978, McNally & Warriss, 1996; Hoffman, Spire, Schwenke & Unruh, 1998) distance travelled as well as journey time did not affect the bruising scores in this trial. Although Namibia is a vast country, cattle transport duration in the central areas is comparatively short. The mean transport time lies at 3 hours with the longest recorded journey lasting eight hours. These comparatively short transport trips in terms of distance and journey duration might be the reason that transport duration could not be linked to bruise levels. It was postulated by Tarrant and Grandin (2000) that the conditions surrounding transport are more important than duration of journey or distance covered. One of the consignments delivered to the abattoir during the investigation period needed 8 hours to cover 118 km of which 110 km were gravel and although the driver stopped 10 times to check on the animals the duration of this journey seemed excessive. The bruising recorded for this particular truck was quite high at 26% and it is assumed that the truck had longer stationary periods within the 8 hours.

However, the amount of gravel roads covered in individual journeys seemed to influence bruising and it could be that this factor was further confounded with journey duration. In the exploratory data evaluation, gravel road was shown to be associated with transport duration.

The design of the vehicle has an influence on bruising during transport. Generally all vehicles used to transport livestock should be free of protruding objects in the area where animals are carried while providing solid footing and secure sidewalls which prevent any parts of the animal from sticking out (Anonymous, 2002). Total truck size and total number of animals in consignment were associated with bruising with larger trucks and consignments recording higher bruise scores. Whether this is due to the fact that larger trucks transport more animals and therefore the chance of bruising is higher or whether the physical size of the truck and actual animal numbers in consignment are responsible for the associations could not be established. In Namibia it is common practice to transport cattle loose in one compartment and the use of moveable barriers is seen in few trucks. Honkavaara, Rintasalo, Ylönen and Pudas (2003) studied the effect of large (3 or 4 animals per pen) and small (1 or 2 animals per pen) compartments on animal welfare and found that two- and single animal pens minimised aggressive behaviour and bruising during transport.

The effect that stocking density has on bruising is well documented. Eldridge and Winfield (1988) showed that both too high and too low stocking densities increased bruising. They argued that in the case of high stocking densities in the event of an animal going down it struggles to get up again as the other animals close over it. Also the downed animal will destabilize other animals causing more animals to lose their footing (Knowles, 1999). At low stocking densities animals need to extend more energy to remain standing as the support of other animals is not given. In this case driving events like braking, cornering and gear shifting can lead to bruising as animals bump into sidewalls and the tailgate of the vehicle. Stocking densities expressed in m^2/animal had a significant influence on the amount of bruising observed in the current investigation (Table 4.3) which is in accordance with findings of Tarrant, Kenny and Harrington (1988) and Tarrant, Kenny, Harrington and Murphy (1992). Contrary to findings from Eldridge and Winfield (1988), in general this study found that animals transported at low stocking densities did not differ in bruising from other consignments which might be due to the fact that these consignments were mostly transported on small trucks driven by the owner of the animals. However, in at least one incident reordered during this investigation, low stocking densities could have influenced the high degree of bruising observed (Trip 10 Figure 4.2).

The high incidence of bruises around the tailbones (butt and pin area) is assumed to be the result of overloading which forces the animals to stand against the side walls of the stock crate and the constant vibration, especially on gravel roads, will manifest in these types of bruises. Similar findings were reported by Wythes *et al.* (1985) yet these authors were able to link the increase in butt and pin bruises to increased transport distances which could not be done in this investigation.

Duration of the journey is considered more important than actual distance covered (Warriss, 1990) - this stems from the fact that road conditions determine travel speed and this is especially true in Namibia. Although the distances travelled were on average 154 km (± 7.2) the actual duration differed greatly and could often be linked to road conditions; more precisely to the amount of gravel roads covered during transport. Also, consignments shipped from the Khomas Hochland area, a very mountainous area west of Windhoek had much lower travel speeds compared with other areas of the country; the reason for this is the poor road conditions in this area. However, bruising did not differ from animals slaughtered from this area.

As mentioned above when comparing levels of bruising and stocking densities of those trucks which came in repeatedly during the trial period the following common variables were noted: low travel speeds, high number of stops to inspect animals, and larger distances travelled on gravel roads. These observations seem to enforce the results of other authors (Tarrant *et al.*, 1992; Tarrant & Grandin, 1993) who found that driving style, road conditions and stocking density were more important than distance and duration of transport. Breaking, gear changes and cornering were the main driving events which caused animal to lose their footing during shorter road journeys (Kenny & Tarrant, 1978a, b; Tarrant *et al.*, 1988). These events are further aggravated by poor road conditions. However, as no direct observations during transport were done during this investigation the above mentioned variables are assumed to affect bruising but no direct statistical evidence could be given.

Bruising recorded for the different locations in this investigation (Figure 4.3) are much higher than those reported by Wythes *et al.* (1985) who found 37% of the bruises on the rump, loin and hips; 24% in the butt and pins; 12% on the ribs 12% and 6% on the back. Grandin (1999) links loin bruises to rough handling during loading and off-loading events causing two excited animals to wedge themselves in the door of the truck, while shoulder bruises occur commonly where animals hit protruding objects such as gate latches or where faulty gates hit passing animals. Grandin further related the incidence of back bruises with faulty equipment such as fall gates as well as horizontal structures in vehicles and facilities. When evaluating bruise location and age in this investigation, a high incidence of bright red bruise on the middle of the rump could be related to the tail gate of the stun box being closed too early before the animals had cleared it completely.

Stationary trucks pose a threat to animals in transit in two forms. Once a truck stops, air-flow is hampered and heat can build up rapidly which will lead to dehydration and heat stress (Grandin & Gallo, 2007); especially during the summer months in Namibia. Furthermore, as mentioned above social interactions are much higher in stationary trucks since animals do not have to concentrate to remain standing. Social interactions will be especially high on trucks where unfamiliar animals were mixed prior to loading. Yet some stops are necessary during the journey in order to inspect the animals; these should however be kept as short as possible.

The weather in Namibia is especially hot during the summer months and can be excessively cold in winter. What is more important is that temperatures can fluctuate severely between minimum and maximum daily temperatures. Minimum daily temperature as recorded in lairage had a significant influence on bruising. As the daily minimum temperature increased, the amount of bruising observed on slaughter increased too. The reason for this is unclear; one possible reason could be caused by vasodilatation which increases the blood circulation nearer to the skin surface. The impact of an object could then lead to rupture of the vessels near the surface causing a bruise while the same impact on an animal where vasoconstriction diverted blood-flow away from the upper layers would not result in such a prominent bruise.

4.4.4 Lairage

The facility design of the lairage at the export abattoir in Windhoek has been described in Chapter 3. The following are descriptions of the areas where bruising could be caused. On off-loading the animals pass through the side door of the truck and step onto the off-loading ramp. Bruising can occur as the animals bump into the door frame on the 90 degree turn to exit the truck (Grandin, 2001) and also when two animals try to exit at the same time thereby wedging themselves in the door. The latter incident is associated with increased loin bruises (Grandin, 1999). At the abattoir in Windhoek animals often balked on reaching the truck doors as the receival-officer of the abattoir was standing at a point in front of the animals on the outside of the curved raceway which would be the side animals would favour to walk on due to their instinctive behaviour.

Animals balking at the door led to excessive use of electric goads. In the observations it became clear that the staff often used an electric goad on animals in the truck that were unable to see the exit as other animals stood in the way. This is an aspect that warrants hands-on training.

Although the animals stepped onto a platform, frequent slips were recorded during off-loading procedures and at least in the preliminary analysis of the data slips could be linked to bruising. Slips showed an association with loading densities in this investigation. The reason for this might be that animals transported at high densities were more tired. Another observation was that the flaps on the trucks which lowered onto the loading ramp to bridge the gap between truck and ramp had insufficient grip and that most animals that slipped lost their footing at this point. This would be aggravated where the soiling of the truck beds started to run onto these flaps and the off-loading ramp making both areas more slippery.

Once the animals were off the truck they had to pass through a sprinkler which contained a dipping agent to kill off ecto-parasites on their way to the holding pens. Animals tended to refuse to pass through at the curtain of water bunching up before it until the first animal passed through. High rates of slipping and bumping into the sides of the raceway as well as into other animals were seen at this point. As animals then went through the central raceway to turn at a 90 degree angle into their designated holding pen, many bumped into the gate posts, which will result in bruising (Grandin, 1993). As animals were removed from the pens before slaughter the 90 degree turn back into the passage way again caused animals to strike the gate post.

Where animals had to be persuaded with the use of electric goads to disembark (Table 4.2) and to move to their holding pens (Table 4.3), bruising was higher than in those consignments where the animals appeared calm and moved to the holding pens at a walk. The incidence of traumatic events like slips and bumping of structures and other animals was higher in animals which ran into the holding pens.

Filling of holding pens was done from front to back and emptying from front to back so as not to disturb resting animals. However, private slaughters (animals slaughtered for other companies or individuals) were done first each day. This could lead to altered emptying patterns and cause disruption in passed pens. Furthermore, cleaning of pens between consignments was done once the animals were removed from the pen in order to receive a new lot. The spraying and washing caused the animals in the adjacent pens to bunch up in corners which could potentially lead to bruising. Eldridge, Warner, Winfield and Vowles (1989) reported higher bruising in animals situated near noisy areas like off-loading and exit to slaughter compared to animals held in quiet areas of the lairage.

Although repeated observations of drinking and resting behaviour as well as social interaction were done in lairage these could not statistically be linked to bruising. However, certain trends became apparent. Free-range animals did not lie down in lairage as frequently and readily as their feedlot counterparts most probably due to the novel flooring encountered in lairage as well as the general novelty of their surroundings. Furthermore, animals that came directly from the farm did not accept the water offered in lairage readily. This could be due to differences in smell and taste or novel watering facilities (Ferguson & Warner, 2008).

4.5 Conclusion

No single factor could be pin pointed as the predominant cause for bruising of animals slaughtered at the export abattoir in Windhoek. The trends noted in this investigation are generally similar to those reported by other researchers. However, some findings of the current study contradict those of other authors and are not easily explained. By nature of the topic of this study confounding effects between measured variables cannot be ruled out. Under Namibian conditions it appears that distance and duration of transport is less important than the conditions prevailing during the event of transportation at least in the case of transport to slaughter within the country. The current study did not consider transport events which transport for extended distance and duration as is the case during live exports from Namibia to its neighbouring countries.

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Chapter 5

Comparison of tenderness between the four major breed types slaughtered in Namibian

Abstract

Breed effects on meat tenderness and water-holding capacity of the *Longissimus dorsi* muscle of the four main breed types (Brahman, Bonsmara, Simbrah and Simmental) used for beef production and the effect of different aging periods on breed differences (2, 9, 16, 23, 30 & 37 days *post mortem*) were investigated. Approximately 50 steers of each breed type of a grading code B (2 - 2½ years of age) and a fat code 2 (1-4 mm subcutaneous fat layer) were included in this study

The Brahman (BRX) differed significantly ($p < 0.05$) from all other breed types at all aging treatments; recording higher Warner-Bratzler shear force values. An interaction between days *post mortem* and breed type were found for the Simbrah (SBX) and Simmental (SX) crosses indicative of a delayed response to aging in the SBX animals presumably due to increased calpastatin activity in these animals. The Bonsmara (BNX) steers showed the highest rate of tenderization and maintained this advantage up to day 30 *post mortem*.

5.1 Introduction

Inconsistent beef tenderness at consumer level is one of the biggest challenges in the meat industry (Koohmaraie, 1996). Although beef eating satisfaction has been linked to a combination of flavour, juiciness and tenderness (Shackelford, Wheeler & Koohmaraie, 1995), Brooks *et al.* (2000) found that inadequate tenderness is the most important factor determining consumer dissatisfaction.

Free-range beef production in Namibia poses multiple challenges in terms of harsh weather conditions, parasites, ease of foraging and predators, this is further complicated by the extensive management practices under which animals are raised and all of these aspects call for resilient breeds/breed crosses which are able to produce and reproduce under these conditions. The four main breed types (Bonsmara, Brahman, Simbrah, and Simmental) slaughtered at the Windhoek export abattoir generally reflect these requirements. The Bonsmara, as a locally developed composite breed, as well as the Brahman and Simbrah breeds are well adapted to the sub-tropical conditions in Namibia. The Simmental breed represents the *B. taurus* breed types and although these breeds are considered less adapted in the tropics it should be mentioned that the Simmental represent the oldest farmed breed type in Namibia after the indigenous Sanga animals (*B. taurus africanus*). The first Simmental animals were introduced to Namibia in 1893 (Anonymous, 2009).

Although meat tenderness depends on a number of biological (e.g. breed, age, sex, muscle type, marbling, etc.) and environmental factors (e.g. nutrition, ante-mortem stress, slaughter and chilling conditions, aging, etc.), research has shown that the production advantages of *B. indicus* and *B. indicus* x *B. taurus* composite breeds in harsher environments are partially negated by problems with beef tenderness (Strydom, 2008; Ferguson, Jiang, Hearnshaw, Rymill, & Thompson, 2000). This combined with consumer demands have led to discrimination of beef derived from these breeds (Pringle, Williams, Lamb, Johnson & West, 1997).

Namibia is a net exporter of beef with South Africa, the EU and Japan being their major markets (Bowles, Paskin, Gutierrez, Kasterine, 2005). All three these markets are very discerning about the quality of the beef that they import. As Namibia has a very small feedlot industry, most of the cattle slaughtered are finished off on natural veldt under free range and extensive conditions and are generally older (2-3yrs) animals, this also results in the free-range beef being tougher than younger feedlot finished animals. The main aim of this investigation is therefore to determine whether there are breed differences (using the four most prominent breeds slaughtered and exported in Namibia) in meat tenderness of older free range Namibian animals and if these can be minimised by aging the meat for a specific time period before consumption.

5.2 Materials and Methods

Fifty steers of each of the four major breed types (mainly crosses) slaughtered in Namibia, Bonsmara (BNX), Brahman (BRX), Simbrah (SBX), and Simmental (SX), were identified in the lairage of the export abattoir. After slaughter only animals with a grading code B (2 - 2½ years of age; Lawrence, Whatley, Montgomery, & Perino, 2001) and a fat code 2 were included in this study. The Namibian carcass grading is similar to the South African grading system as it is based on dentition. Table 5.1 presents a summary of the Namibian beef classification system. The following carcass characteristics are evaluated during classification under this system: age (number of permanent incisors); sex, fatness; body conformation (muscling); and bruising – the later three characteristics are judged subjectively (personal communication Stanely, 2009).

Table 5.1 Summary of the age and fat classification codes used to classify Namibian beef

Age* description	Age classification code	Fat description	Thickness of subcutaneous fat layer (mm)	Fat class code
0 Teeth	A	No fat	0	0
1-2 Teeth	AB	Very lean	<1	1
3-6 Teeth	B	Lean	1 - 4	2
7-8 Teeth	C	Lean	4.1 - 7	3
		Fat	7.1 - 9	4
		Over fat	9.1 - 11	5
		Excessively over fat	> 11	6

* Number of permanent incisors

Animals originated from different production areas in Namibia as well as from different producers. Those animals included in this study were all raised under free-range conditions.

All animals were killed according to the standard slaughter procedures of the export abattoir i.e. – stunning by captive bolt, hoisted by the hind leg, live weight determination, exsanguination, evisceration, carcass classification, hot weight determination and placing in the cooler (4 ºC). No electrical stimulation was applied.

After 48 hrs the carcasses were removed from the coolers and deboned. The striploin (*Longissimus dorsi*) from carcasses quartered between the 10^{th} and 11^{th} rib was removed from the left side of identified carcasses, cut into 6 ± 1.5 cm steak slices which were then vacuum packed individually. The weight of each steak was noted down as well as the pH at 48 hours *post mortem* (pH_{48}). The pH was determined using a hand held pH meter (Testo-205) which was calibrated in buffer solution pH 4.0 and 7.0 after every 15 - 20 measurements. Afterwards the steaks were randomly allocated to different aging treatments (2, 9, 16, 23, 30 and 37 days of aging) packed in boxes and stored at 4ºC until they were evaluated.

The following physical measurements were done on the individual steaks:

1. Purge loss: Purge loss refers to weep/water loss seen in vacuum packed meat. In the lab the individually packed steaks were removed from their bags, gently dried between absorbent tissues and weighed. Percentage purge loss is calculated as the weight loss expressed as a percentage of the original sample.
2. Cooking loss: The sample steaks were placed in sealed plastic bags which were placed in a warm water bath at 80ºC for 60 min. The bagged samples were then removed from the water bath and cooled down under running water to room temperature (± 25ºC). After removing the samples from the bags, samples were dried and weighed again and the cooking loss determined as total fluid lost, expressed as percentage of the fresh (uncooked) sample.
3. Toughness: Five 1.27 cm ø (cylindrical core) core samples were taken randomly from the centre of the cooked striploin steaks to determine Warner-Bratzler shear force values. The samples were cut parallel to the muscle fibre direction in order to measure the influence of the myofibrillar proteins on toughness. Maximum shear force values (kg/1.27 cm ø) to shear a cylindrical core of cooked meat (at a crosshead speed of 3.33 mm/s) were recorded five times for each sample and a mean was calculated for each individual steak using a Warner-Bratzler Shear attachment (with a circular cross section of 1.27 cm ø blade) fitted to an electrical scale programmed to measure maximum weight (force) (Hoffman, Mostert, Kidd & Laubscher, 2009).

Statistical analysis was done using SAS Enterprise Guide 3.0 (SAS, 2006). Sources of variation were investigated by analysis of variance (ANOVA) with days *post mortem* and breed as factorial effects. The quality variables purge loss, cooking loss, pH and Warner Bratzler Shear Force (WBSF) values were compared between breeds as well as between aging treatments. The Bonferroni Multiple Comparison Method at the 5% level was used to separate least significant means (LSMeans).

5.3 Results

Analyses of variance for the four measured quality traits are presented in Table 5.2. An interaction was observed between days *post mortem* x breed type for shear force values. This interaction is depicted in Figure 5.1 between the Simbrah (SBX) and Simmental (SX).

Table 5.2 Analysis of variance for purge loss, cooking loss, pH and shear force at day 2, 9, 16, 23, 30 and 37 days *post mortem*

		% partial contribution to model			
Trait	**DF**	**Purge loss (%)**	**Cooking loss (%)**	**pH**	**Shear force**
Days *post mortem*	1	23.96***	2.64***	19.10***	13.73***
Breed type	3	0.10	1.82***	0.49*	2.11***
Days *post mortem**Breed type	3	0.14	0.06	0.03	0.22*
Mean		3.43	35.12	5.69	3.80
CV		60.92	5.35	8.98	26.89
R^2 model (%)		24.36	7.65	20.99	19.03

*p < 0.05;**p < 0.001;*** p < 0.0001; DF – degrees of freedom

The SBX have lower LSMean shear values on day 2 *post mortem* compared to the SX, this trend reverses between day 2 and 9 *post mortem* indicating that *post mortem* tenderization is higher in the SX. The interaction found for the tenderness measurements is significant ($p < 0.05$), however, its partial contribution to the model is very small (0.22%) and for this reason the main effects will also be discussed for this measurement.

Although breed type had no influence on purge loss; it had a significant influence on pH and a highly significant influence on cooking loss and shear force values.

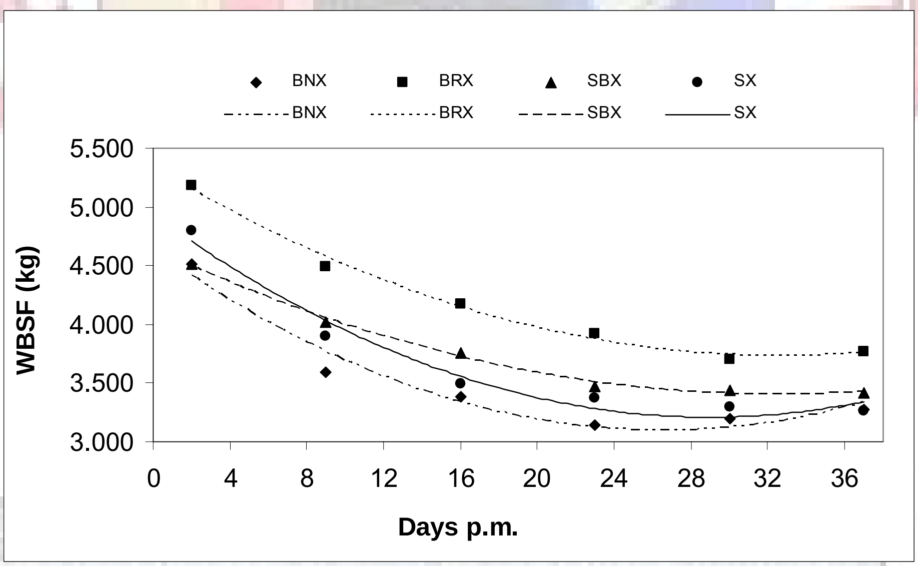

Figure 5.1 Changes in meat tenderness (determined using Warner Bratzler Shear Force) of four breed-types over the aging period of 37 days *post mortem* (p.m).

Days *post mortem* has a highly significant influence on all four measured quality traits. The amount of purge loss increased over aging time (Figure 5.2) and a similar trend was observed for cooking loss (Figure 5.3). pH changes over the individual aging days followed a curvilinear trend, while the overall trend was a slight increase over the total aging period (Figure 5.4). As expected, shear force values decrease over the aging period (Figure 5.1).

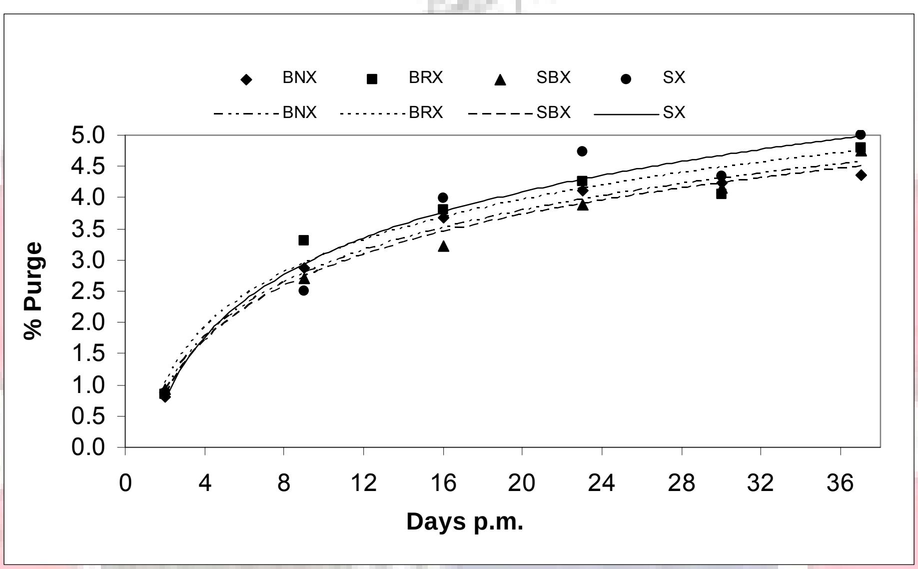

Figure 5.2 Changes in striploin purge loss of four breeds over aging period of 37 days *post mortem* (p.m.).

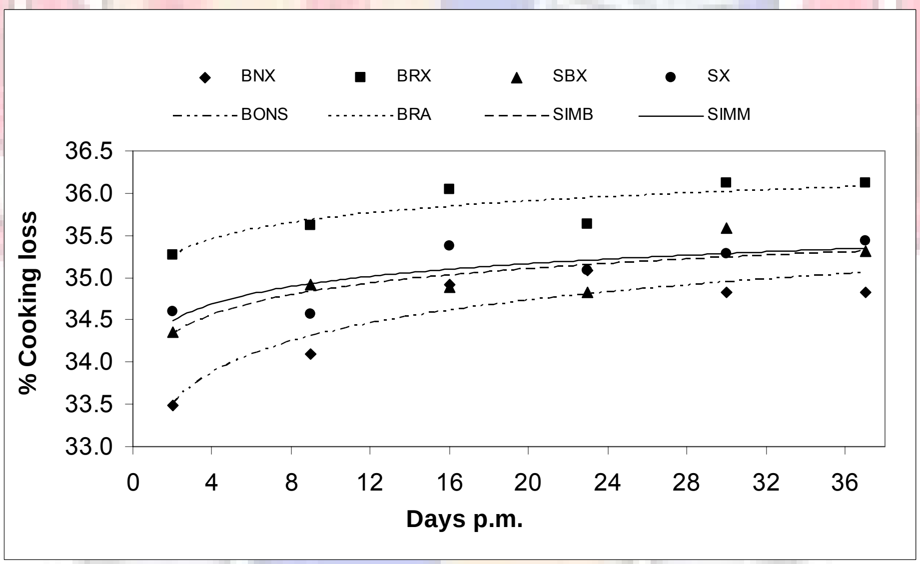

Figure 5.3 Changes in striploin cooking loss of four breed-types over aging period of 37 days *post mortem* (p.m.).

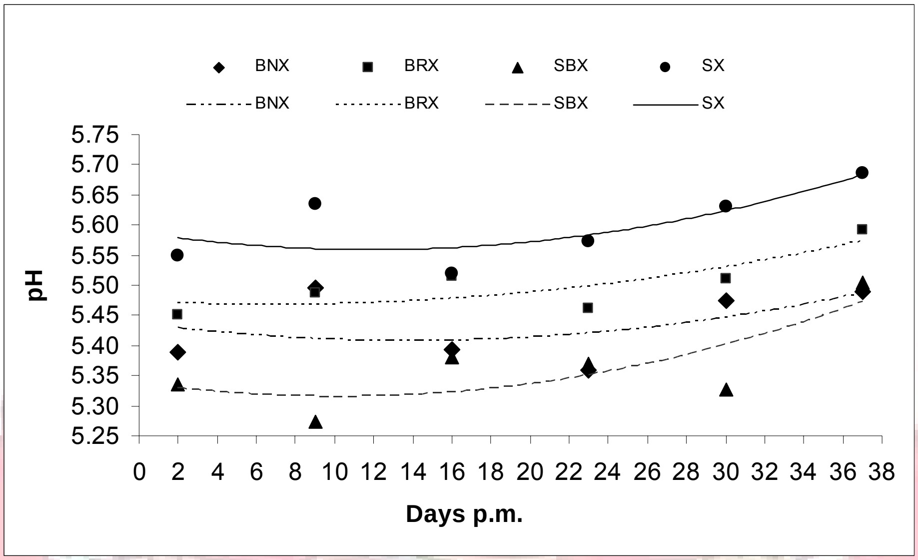

Figure 5.4 Changes in striploin pH of four breed-types over aging period of 37 days *post mortem* (p.m.).

The least square means for the four quality traits are summarized in Table 5.3 with superscripts identifying means which differ significantly within and between individual days of aging.

Cooking loss is higher ($p < 0.05$) in Brahman (BRX) steers than Bonsmara (BNX) over the total aging time except for day 23 *post mortem*. The SX steers differed from the BNX only on day two *post mortem* while the SBX only differed from the BRX on day 16 *post mortem.* For the other aging times the SX and SBX animals were intermediate between the BNX and BRX.

The changes in pH on consecutive aging days differed between the breeds and these differences were mostly due to the fact that the different breeds were on different parts of the curvilinear cycle that pH displays in this data. The general pattern can be described as increasing, decreasing then increasing again. The initial increase after reaching the pH_{48} is due to protein break down which frees hydrogen ions (Huff-Lonergan & Lonergan, 2005). In the SBX group pH drops until day nine *post mortem* compared to all other breeds which show an increase in pH between day 2 and day 9, this inconsistency in the pattern cannot be explained and may be due to sampling bias. The increase in pH lasts up to day 9 for the SX and BNX after which it starts to decrease while it increases up to day 16 in the BRX and SBX. However, statistically no model could be fit to these changes in pH.

Throughout the aging period the BRX animals differ significantly from all other breed types in terms of tenderness. The overall pattern in tenderness change shows the BNX to have the lowest WBSF values and the BRX the highest with the other two breed types lying in between (Figure 5.1).

Although the other three breeds do not differ on day 2 after slaughter the BNX are significantly different from the SBX animals on day 9 to 30 of the aging period while the BNX differs from the SX on day 9 and 23.

For further analysis the shear values were categorized into three classes according to threshold levels reported by Shackelford, Morgan, Cross and Savell (1991) who found that 4.6 kg and 3.9 kg values were quite accurate in determining whether or not a steak would be rated less than ‘slightly tender’ by trained sensory panels and consumer panels. The three groups can be described as “tender” (< 3.9 kg), "intermediate" (3.9 – 4.6 kg) and "tough" (> 4.6 kg). Although it is known that WBSF measurements vary between different institutions (Wheeler, Koohmaraie, Cundiff & Dikeman, 1994) which effects mean shear force values and the repeatability of shear values among institutions, the values of Shackelford *et al.* (1991) were considered suitable to describe the data of this investigation.

Table 5.3 Least square means (± s.e.) for purge loss, cooking loss, pH and Warner-Bratzler shear-force (WBSF) values by breed at respective days of aging

Days p.m.	Breed type	N	Purge loss (%)	N	Cooking loss (%)	N	pH	N	WBSF (kg)
2	BNX	50	0.80 ± 0.04	50	33.48 ± 0.27^{b}	50	5.39 ± 0.03^{bc}	50	4.508 ± 0.085^{bw}
	BRX	52	0.85 ± 0.04	52	35.27 ± 0.27^{a}	52	5.45 ± 0.03^{ab}	52	5.182 ± 0.083^{aw}
	SBX	53	0.92 ± 0.04	53	34.35 ± 0.27^{ab}	53	5.34 ± 0.03^{c}	53	4.512 ± 0.082^{bw}
	SX	50	0.87 ± 0.04	49	34.60 ± 0.28^{a}	49	5.55 ± 0.03^{a}	50	4.797 ± 0.085^{bw}
	Mean	**205**	**0.86 ± 0.02**	**204**	**34.43 ± 0.14**	**204**	**5.41 ± 0.02**	**205**	**4.750 ± 0.043**
9	BNX	50	2.87 ± 0.10	49	34.52 ± 0.26^{b}	50	5.50 ± 0.02^{b}	50	3.587 ± 0.076^{cx}
	BRX	51	2.85 ± 0.10	52	35.61 ± 0.26^{a}	52	5.49 ± 0.02^{b}	52	4.496 ± 0.074^{ax}
	SBX	53	2.71 ± 0.10	52	34.92 ± 0.26^{ab}	53	5.27 ± 0.02^{c}	53	4.019 ± 0.074^{bx}
	SX	41	2.78 ± 0.11	42	34.57 ± 0.28^{ab}	42	5.63 ± 0.03^{a}	42	3.897 ± 0.083^{bx}
	Mean	**195**	**2.80 ± 0.05**	**195**	**34.82 ± 0.17**	**197**	**5.46 ± 0.01**	**197**	**4.009 ± 0.040**
16	BNX	50	3.67 ± 0.14	50	34.91 ± 0.26^{b}	50	5.39 ± 0.03^{b}	50	3.386 ± 0.073^{cxy}
	BRX	50	3.62 ± 0.14	52	36.04 ± 0.25^{a}	52	5.51 ± 0.03^{a}	52	4.175 ± 0.072^{ay}
	SBX	52	3.42 ± 0.13	53	34.88 ± 0.25^{b}	53	5.38 ± 0.03^{b}	53	3.760 ± 0.071^{bxy}
	SX	49	3.72 ± 0.14	50	35.37 ± 0.26^{ab}	50	5.52 ± 0.03^{a}	50	3.495 ± 0.073^{bcy}
	Mean	**201**	**3.61 ± 0.07**	**205**	**35.30 ± 0.13**	**205**	**5.45 ± 0.01**	**205**	**3.710 ± 0.038**
23	BNX	49	3.63 ± 0.13	50	35.08 ± 0.28	50	5.36 ± 0.03^{b}	50	3.146 ± 0.062^{cy}
	BRX	50	3.92 ± 0.13	52	35.63 ± 0.27	52	5.46 ± 0.03^{ab}	52	3.925 ± 0.061^{ayz}
	SBX	53	3.89 ± 0.13	53	34.82 ± 0.27	53	5.37 ± 0.03^{b}	52	3.476 ± 0.061^{byz}
	SX	49	4.03 ± 0.13	50	35.09 ± 0.28	50	5.57 ± 0.03^{a}	50	3.377 ± 0.062^{by}
	Mean	**201**	**3.91 ± 0.08**	**205**	**35.16 ± 0.14**	**205**	**5.44 ± 0.02**	**204**	**3.485 ± 0.032**
30	BNX	50	4.23 ± 0.14	48	34.82 ± 0.29^{b}	50	5.48 ± 0.03^{b}	50	3.202 ± 0.061^{cy}
	BRX	52	4.05 ± 0.14	52	36.12 ± 0.27^{a}	52	5.51 ± 0.03^{ab}	52	3.704 ± 0.060^{az}
	SBX	52	4.14 ± 0.14	52	35.59 ± 0.27^{ab}	50	5.31 ± 0.03^{c}	52	3.441 ± 0.060^{bz}
	SX	49	4.35 ± 0.15	49	35.28 ± 0.28^{ab}	49	5.63 ± 0.03^{a}	49	3.298 ± 0.062^{bcy}
	Mean	**203**	**4.19 ± 0.07**	**201**	**35.47 ± 0.14**	**201**	**5.48 ± 0.02**	**203**	**3.415 ± 0.031**
37	BNX	50	4.36 ± 0.15	49	34.83 ± 0.24^{b}	50	5.49 ± 0.03^{b}	50	3.276 ± 0.064^{by}
	BRX	50	4.94 ± 0.15	51	36.13 ± 0.24^{a}	51	5.59 ± 0.03^{ab}	51	3.767 ± 0.063^{az}
	SBX	52	4.57 ± 0.15	53	35.31 ± 0.23^{ab}	52	5.48 ± 0.03^{b}	53	3.414 ± 0.062^{bz}
	SX	50	5.00 ± 0.15	50	35.44 ± 0.24^{ab}	50	5.69 ± 0.03^{a}	50	3.269 ± 0.064^{by}
	Mean	**202**	**4.72 ± 0.08**	**203**	**35.43 ± 0.12**	**203**	**5.56 ± 0.02**	**204**	**3.433 ± 0.032**

^{a,b,c} Column means for breed types within different days of aging with different superscripts differ (p<0.05)
^{w,x,y,z} Column means for breed types between different days of aging with different superscripts differ (p<0.05)

The data depicted in Figure 5.1 was fitted with polynomial models and the resulting equations used to calculate the days *post mortem* it takes the different breeds to reach intermediate (4.6 kg) and tender (3.9 kg) shear force values. These results are depicted in Table 5.4. The BNX and SBX reach mean 'intermediate' WBSF values before day 2 after slaughter while the SX reaches these values around 3 days *post mortem* and the BRX around 9 days. It takes the BNX, BRX, SBX and SX 7, 22, 12 and 11 days of aging respectively to reach ‘tender’ shear values

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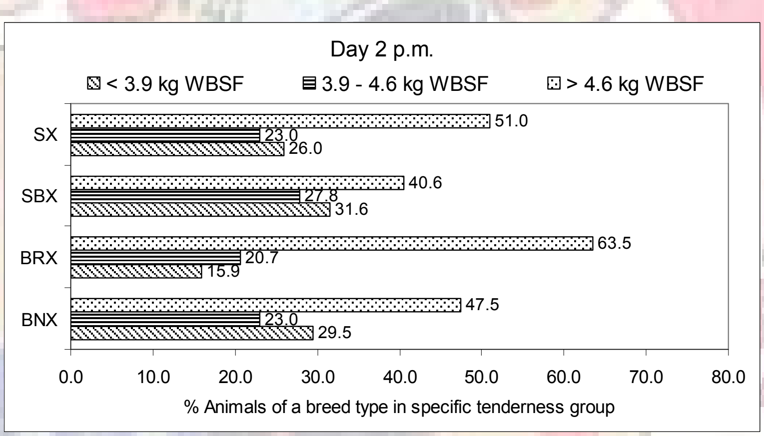
Table 5.4 Polynomial equations fitted to Warner-Bratzler shear-force (WBSF) values, describing the improvement of tenderness over aging time

Breed type	**Polynomial Equation**	**R^2**	**Days until WBSF 4.6 kg**	**Days until WBSF 3.9 kg**
BNX	$y = 0.0022x^2 - 0.1161x + 4.6379$	0.9579	-	7.38
BRX	$y = 0.0015x^2 - 0.0984x + 5.3384$	0.9921	8.51	21.89
SBX	$y = 0.0012x^2 - 0.0764x + 4.6465$	0.9947	-	11.91
SX	$y = 0.0021x^2 - 0.1192x + 4.9378$	0.9704	2.90	10.73

The changes in tenderness class within breed types over the aging period of 37 days are shown in Figure 5.5a and b. The most noticeable change takes place between day 2 and 9 *post mortem* with the percentage of animals moving from group C (> 4.6 kg) to group B (3.9 – 4.6 kg) and A (< 3.9 kg). Furthermore it can be seen that the BNX rate of tenderizing is much higher compared to the other breeds. It is also visible on the figure that tenderness improves up to 30 days *post mortem* while a slight decrease in tenderness is observed for all breed types on day 37 *post mortem.* This increase is assumed to be the result of moisture loss resulting in there being more fibres per unit area which will increase shear values.



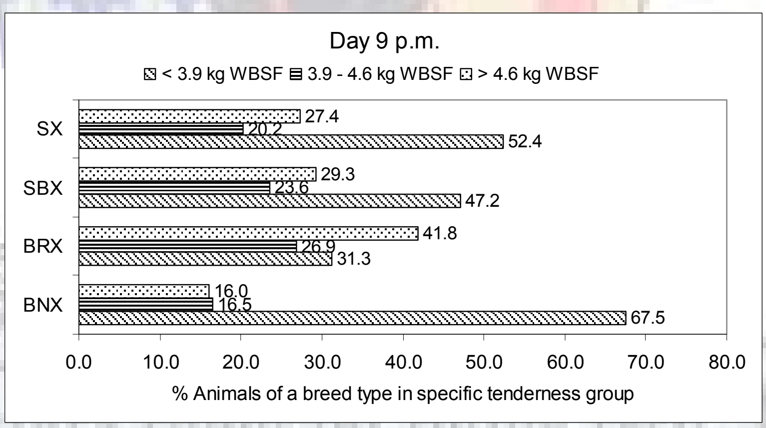


Figure 5.5a Change in tenderness class for four different breed-types for days 2 and 9 *post mortem*.

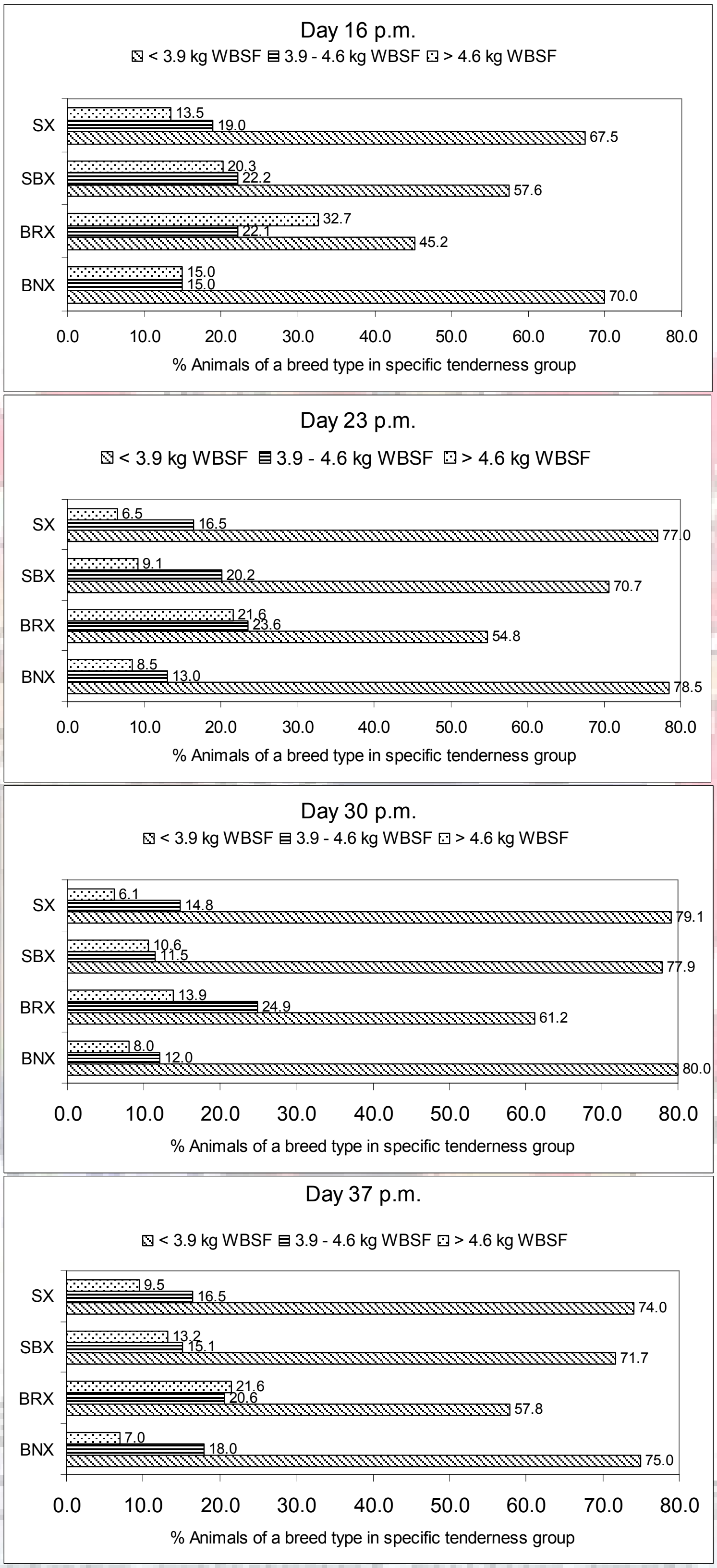


Figure 5.5b Change in tenderness class for four different breed-types for 16, 23, 30 and 37 *post mortem*.

5.4 Discussion

Juiciness is one of the attributes linked to meat eating satisfaction (Shackelford *et al*., 1995). The amount of water found in meat influences its juiciness and therefore palatability as well as saleable weight of the product. Water is lost from the meat by evaporation, in the form of drip or purge and also during cooking (Hertog-Meischke, Smulders, & van Logtestijn, 1998). Water exists in muscle in three forms; bound to proteins (this fraction is not affected by freezing and not lost during conventional cooking); entrapped water held either by steric effects and/or by attraction to bound water; and free water (Huff-Lonergan & Lonergan, 2005). The fraction which is most affected by the conversion of muscle to meat is the entrapped water. During *post mortem* aging pH decreases (mainly due to lactic acid conversion in the muscles) until it reaches the iso-electric point of the main proteins reducing the net charge of these proteins to zero. This means that the attraction of water is reduced and the repulsion of structures within myofibrils is reduced allowing the components to move nearer to each other (lateral shrinkage) (Huff-Lonergan & Lonergan, 2005). This effectively reduces the space available for water and the water manifests as drip or purge (purge loss describes the water visible in vacuum packed meat).

Although the amount of purge loss increased over aging time, no differences in purge loss between breeds were recorded in this investigation. Muchenje, Dzama, Chimonyo, Raats and Strydom, (2008) and du Plessis and Hoffman (2007) reported similar findings in pasture raised animals in South Africa. Contradictory results were reported by Jama, Muchunje, Chimonyo, Strydom, Dzama and Raats, (2008) who found a decrease in drip loss over an aging time of 21 days.

Reasons for the differences in cooking loss between breeds reported in this investigation (Table 5.2) are unknown and contradict the findings of Jama *et al.* (2008) who found no differences in cooking loss between breeds. It could be postulated that the differences in pH between breeds within aging treatments is responsible for the differences seen in cooking loss in this investigation as water holding capacity is influenced by pH. Bruce, Stark and Beilken (2004) reported that rapid pH fall, as induced by short-term stress, can reduce water-holding capacity especially in stress susceptible animals. This argument is supported by Petherick, Holroyd, Doogan and Venus (2002) who reported that initial pH levels in poor-temperament animals were lower and that this was caused by conversion of glycogen to lactic acid immediately before slaughter. *B. indicus* bred animals reportedly have poorer temperaments than their *B. taurus* counterparts (Hearnshaw & Morris, 1984; Fordyce, Dodt & Wythes, 1988). Thus the higher cooking loss observed in the BRX could be the result of short-term stress in these animals. Long-term stress on the other hand leads to higher ultimate pH values (above iso-electric point of muscle proteins) and improves water-holding capacity by improving the space available for water (Bruce *et al.*, 2004).

Connective tissue content, sarcomere length and protein proteolysis are the primary sources of meat tenderness variation. Connective tissue components are believed to be responsible for the variation observed in background toughness, in particular the organization of the perimysium (Strandine, Koonz & Ramsbottom, 1949). Background toughness was defined by Marsh and Leet (1966) as “the resistance to shearing of the muscle before shortening occurred” and is a factor which exists at slaughter and does not change during aging (Koohmaraie & Geesink, 2006).

The toughening phase starts with *rigor mortis* development and is caused by sarcomere shortening (Koohmaraie, Doumit & Wheeler, 1996). This phase is similar in carcasses handled under similar processing conditions (Luciano, Anton & Rosa, 2007). The tenderizing phase starts directly after slaughter and varies greatly both in rate and extent of *post mortem* meat tenderization. It is this variation which causes the inconsistency in tenderness observed at the consumer level (Koohmaraie & Geesink, 2006). Proteolysis of key myofibrillar and myofibrillar-associated proteins forms the basis of the tenderizing phase (Koohmaraie & Geesink, 2006). The primary proteolytic enzyme system involved in post mortem tenderization of aged beef is the calpain system, which consists of two calcium requiring enzymes, μ-calpain and m-calpain, as well as an inhibitor, calpastatin (Koohmaraie, 1996). Other factors such as temperature, pH and calcium ion concentration can further influence this process (Takahashi, 1996).

The difference in tenderness between *B. indicus* and *B. taurus* are well documented and it appears that it is mainly the result of calpastatin activity in *post mortem* muscle. The lower tenderness in the BRX (Figure 5.1; Table 5.2) observed is in accordance with the findings of Crouse, Cundiff, Koch, Koohmaraie, and Seideman (1989); Whipple, Koohmaraie, Dikeman, Crouse, Hunt and Klemm (1990); Johnson, Calkins, Huffman, Johnson, and Hargrove (1990-b); Johnson, Huffman, Williams and Hargrove (1990-a); O'Connor, Tatum, Wulf, Green and Smith (1997), Pringle *et al.* (1997) and Ferguson *et al.* (2000) who reported higher shear force values for *B. indicus* and *B. indicus* cross animals and most authors linked these to differences in *post mortem* proteolysis. Both O'Connor *et al*. (1997) and Pringle *et al.* (1997) measured calpastatin activity in their investigations and concluded that the increased calpastatin activity found in *B. indicus* breeds is one factor which is responsible for the lower rate and extent of proteolysis observed in these animals. The interaction between the SX and SBX (Figure 5.1) recorded in this investigation is an indication for the delayed onset of aging in *B. indicus* composite breeds. Similar interactions between breed x aging time have been reported by Johnson *et al.* (1990-a), and Stolowski *et al.* (2006) for Brahman and Angus cattle. O'Connor *et al.* (1997) also found that biological type interacted with aging and reported that, as the percentage Brahman inheritance increased, the rate and extent of tenderization during aging decreased.

Although the interaction between SX and SBX is significant ($p < 0.05$), the difference in tenderness over the aging period is not. Indicating that *B. indicus* composite and cross bred animals can have similar shear values as the European breeds. Although the percentage Brahman inheritance of the SBX steers used in this trial is unknown, it could be postulated that their Brahman inheritance does not influence their tenderness values. Johnson *et al*. (1990-a) showed that differences in tenderness only became significant when the percentage Brahman breeding reached fifty percent, while Stolowski *et al*. (2006) found that calpastatin levels were highest in the *M. longissimus dorsi* in animals with 50% *B. indicus* breeding.

The Bonsmara breed is made up of 5/8 Afrikaner and 2/8 Hereford and Shorthorn and it might be due to its *B. taurus* inheritance that this breed type showed the lowest shear values throughout the trial period. Strydom, Naude, Smith, Scholtz and van Wyk (2000) reported similar results when comparing *B. indicus* with *B. taurus africanus* breeds.

5.5 Conclusion

Clear breed differences were found for cooking loss and tenderness between the four main breed-types slaughtered in Namibia. The reason for the differences in cooking loss between breeds might be linked to pH. Tenderness differences between breeds reported are in accordance with other research.

Aging clearly improved tenderness in all breeds. However, in animals with *B. indicus* breeding rate of tenderization was lower compared with the BNX and SX. And although the extent of tenderization was decreased in the BRX animals this was not reflected in the SBX which reached the same tenderness levels as the BNX and SX animals.

The results of this study should not lead to the discrimination of any breed-type as the market structure of the Namibian beef exports allows the exploitation of the shipping times it takes the beef to reach the EU markets which are long enough for beef from *B. indicus* crossbred animals to age sufficiently. Thus, if the beef is sorted according to breed-type and then assigned to the different markets, good quality could be maintained.

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Chapter 6

Good management procedures during handling and transport

6.1 Introduction

Animal welfare considerations have evolved from the principle of preventing cruelty to animals to a much more elaborate approach of ensuring welfare at all production stages of an animal's life. This resulted in the revision of legislation and adoption of model codes of practice in many countries around the world. Especially in the developed countries, where current day consumers are interested not only in the origin of their food source but also the impact its production has on welfare and sustainability, new legislation has been drawn up by governments to safeguard this interest of their citizens. This legislation often affects other countries who want to export their commodities to these nations and in order to do so they have to comply with the requirements of these trading partners. The introduction of the Farm Assured Namibian Meat scheme (FAN Meat) in 1999 was Namibia's answer to meet the European Union requirements for traceability and animal welfare standards. The FAN Meat system traces an animal from birth to slaughter and there is to date "no comparable scheme operating in Africa which is as highly regarded in terms of traceability and animal welfare" (Bowles *et al.*, 2005). However there is a need to extend the FAN Meat system to include a more active approach to ensuring animal welfare.

The current investigation is the first practical field research on the Namibian transport event and its effect on animal welfare. A high incidence of bruising showed that much still needs to be done to improve welfare during transportation and its associated handling. However, this study only reflects the transport situation in the central areas of Namibia and only for cattle destined for slaughter at the export abattoir in Windhoek. Therefore, the reported transport distances and duration are not representative of all animals transported in Namibia. Livestock exported live to neighbouring countries, especially South Africa, will be transported for much longer distances and duration and this has to be considered in any code of practice. The aim of this chapter is to put the results in context with good management practices/procedures for cattle handling and transport which should be adopted to improve welfare in the Namibian Meat Industry.

6.2 Summary of results

The following results obtained from this study considering animal welfare aspects is considered for drafting an outline for a code of practice for handling and transport of cattle:

- Re-branding of animals in order to facilitate legible brands increased bruising ($p < 0.05$).
- Loading densities in square meter per animal ($p = 0.06$) affected bruising negatively and poor welfare due to too high densities was further reflected in the increased bruising resulting from animals going down during transport.

- Vehicle and facility design became important when on off-loading. The fit between off-loading ramp and truck floor ($p < 0.05$) forced animals to step up or down and resulted in more slips and falls compared to level fits.
- The size of holding pens in lairage was implicated in increased bruising ($p < 0.05$), with the larger pens having higher levels of bruising.
- Minimum temperature changes from 8 - 16º C (during winter) saw a concomitant increase in the number of bruises observed on slaughter ($p < 0.0001$).
- Animal factors which had an influence on bruising included sex ($p < 0.0001$) and age of the animals, as well as live weight ($p < 0.0001$), the visual condition ($p = 0.005$) and fat score ($p < 0.05$). The presence of horned animals in consignments further influenced bruise levels observed in this study ($p < 0.05$).

6.3 Current Namibian legislation and guidelines governing animal welfare during handling and transport

In Namibia the Animals Protection Act 71 of 1962 (Anonymous, 1962), is the only piece of legislation which considers animal welfare. However, this Act addresses proven acts of cruelty rather than setting standards. The FAN Meat Manual, which forms the basis of the FAN Meat scheme, offers a more current approach to animal welfare practices. It is however not enforceable by law and depends solely on the goodwill of its participating stakeholders. The original FAN Meat guidelines are presently being revised in order to accommodate new knowledge in the field of animal welfare as well as address areas which were not sufficiently comprehensive. Table 6.1 is a summary of the welfare standards which will be covered by the revised FAN Meat guidelines (personal communications, Dr. Thalwitzer, 2009).

Table 6.1 A summary of the animal welfare standards which form part of the revised FAN Meat guidelines

Issue	Standard and animal welfare application
Producer	Livestock owners are responsible for the welfare of their animals and must ensure that they are aware of all welfare requirements; Handling facilities must be designed to facilitate good handling and prevent injury and stress to animals; Animals should be handled in such a way as to minimize stress and injury; Animals should have access to clean water and adequate feed at all times; Sick and injured animals must be treated promptly or euthanized.

Table 6.1 continued A summary of the animal welfare standards which form part of the revised FAN Meat guidelines

Issue	Standard and animal welfare application
Livestock agents, brokers and traders	Livestock agents, brokers and traders have to ensure that the vehicle arranged by them to transport the animals complies with the minimum standards laid down in the Manual; Provide loading and off-loading facilities at sale-yards designed to facilitate ease of handling and prevent stress and injury to animals.
Livestock transporters	Vehicle design which safeguards animals and prevents stress and injuries; Ensure that appropriate loading densities appropriate to the type and condition of the animals transported are maintained; Transporters should assure that drivers control vehicle (drive) in such a way as to avoid injury and stress to the animals; Loading and off-loading are done promptly and without delay, avoiding injury and stress to the animals; Drivers should inspect the animals during transit to ensure their welfare; The maximum permitted journey time (8 hours) is adhered to, and where necessary rest stops held.
Export abattoirs	Abattoir management has to ensure that all off-loading and handling is carried out with all animal welfare requirements in mind; Off-loading and handling facilities must be designed to prevent stress and injury to livestock; Abattoir must ensure that ante-mortem inspections are carried out by a veterinary.

6.4 The need for a model code of practice

In light of the little legislation governing animal welfare in Namibia the need to develop a model code of practice which establishes good management practices to ensure animal welfare during handling and transport for the Namibian Livestock industry has already been emphasised in the National Agricultural Support Services Programme (NSSAP) report in 2006 (Anonymous, 2006a). The authors of this report identified the following points which should be addressed in the model code:

- Responsibilities
- Licensing of transporters and drivers
- Construction of loading, handling facilities and vehicles
- Minimising stress and pre-transport management
- Fit to load
- Loading density (that provides a range rather than a specific figure)

- Loading and unloading
- Length of journey and rest periods
- Emergency procedures

Although not all of the above points fall into the scope of this study, most will be briefly discussed in the following sections as they are interlinked and a holistic approach will facilitate better welfare outcomes than concentrating on singular events in the transportation chain of events.

6.4.1 Responsibilities

In most cases where animals are transported they concomitantly change ownership. This often causes a conflict in responsibility for the animals and can therefore compromise their welfare. It is important that clear areas of responsibility must be determined for different stages of the transport chain. How these responsibilities will be distributed depends on the specific structures of the industry, especially where insurance schemes are in place which 'protects' stakeholders from the consequences of bruising and poorer meat quality. Furthermore, where the transporters are not integrated in the production chain incentives to secure their interest in welfare aspects should be created. Responsibilities for animals transported across boarders as seen in the event of live exports needs special attention as their will be confusion on which countries legislation applies to these transports.

6.4.2 Planning of transport

Planning of the transport event well in advance is important in countries like Namibia where spaces are vast and help is not necessarily available or reachable at all times. This could result in dire consequences in the event of a breakdown which would leave animals standing on a truck without shade and ventilation. Therefore before the advancement of any journey transporters should make sure that the designated truck is in such a condition that it will reach its destination without delay provided no unforeseen circumstances arise during the journey.

The vehicle and stock crates should be designed as to be appropriate for the animals carried in terms of size and weight and care should be taken to maintain the area where animals are held on the vehicle to be free of protruding objects which could injure animals. More on the need for vehicle design will be discussed later in the text.

Routes should be planned in advance and special consideration given to areas where delays could occur due to roadwork, borders or high traffic which will unnecessarily increase driving events like breaking and accelerating and extended periods where the vehicle is stationary. Where possible such areas should be avoided.

Contingency plans should be in place for all predictable events which could happen during transport. Drivers should be in possession of technology which gives them the chance to request help when necessary. Next to the telephone number of their employer they should be supplied with the contact details of the producer whose animals they are transporting as well as any other authority able to help in the case of an emergency.

Depending on the length and duration of the journey, stops to inspect the animals during transit should be held to prevent unnecessary suffering if an animal goes down or shows any other signs of acute stress for any such event the driver should be trained to deal with the situation. However, results of the current study show that too many stops slowed down journeys considerably and resulted in increased bruising which is either the result of the driving event of breaking to stop then accelerating again and/or social interaction between animals on stationary trucks. This also emphasises the importance of driving style on animal welfare which will be discussed later in the text. All persons driving livestock should be trained in emergency procedures and a protocol should be available on how to proceed in the case of break downs and accidents.

6.4.3 Design and maintenance of facilities, vehicles and equipment

Facility and vehicle design have a direct influence on ease of handling and it has been shown that handlers forced to work with faulty equipment and lacking facilities often show less consideration for the animals they work with (Jarvis, Selkirk & Cockram, 1995). Therefore, the benefits of well designed and maintained facilities are twofold in improving animal welfare during handling and transport.

Stress during handling and transport can be minimized by considering inherent animal behaviour and integrating that into facility design. Wide-angle (360º) panoramic vision enables cattle and sheep to see behind them without turning their heads (Grandin, 2001) and although grazing animals can perceive depth they need to stop and lower their heads to accurately see depth. In general livestock will be inclined to stop when encountering one of the following situations: shadows, water puddles, drain grates, shiny objects, flapping objects, dogs, a bright spot of sunlight in an otherwise darker area, or loose dangling chains (Grandin, 2001) and where ever possible these should be eliminated in handling areas (Grandin, 2007a).

Circling around the handler in order to always keep him/her in view is a natural tendency that has been observed in both cattle and sheep. Incorporating this behaviour has led to the development of curved raceways and chutes (Figure 1).

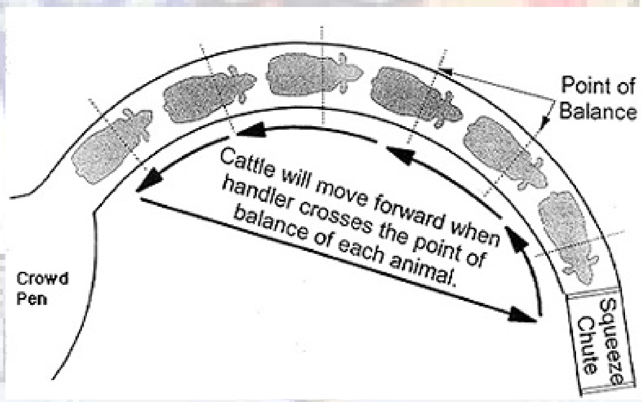

Figure 1 Handler movement pattern to keep cattle moving into the squeeze chute in a curved chute system (adapted from Grandin, 2001)

From the above it can be deducted that ease of movement is facilitated by even illumination which does not cast shadows as animals pass, handling facilities which eliminate visual distractions and utilize the animals' natural following behaviour. Solid walls prevent animals from seeing handlers or other distractions, while curved raceways can prevent animals from baulking at dead-ends (Warriss, 1990). Furthermore, well drained non-slip flooring is important to prevent animals from falling or bumping into structures.

Another factor that should be considered when handling animals is their acute sense of hearing which will cause them to get spooked and stressed by loud noises. Therefore, handling facilities and transport vehicles should be free of parts which cause unnecessary noises (Grandin, 2008).

Holding pen shape as well as arrangement to walkways and races has been shown to influence social behaviour and bruising (Grandin, 2007b). Animals are more inclined to lie down near the perimeter of an enclosure than it's the middle and will react negatively when other animals invade on their personal space (Strickland, 1978). Therefore, rectangular pens which have a greater perimeter are thought to improve welfare. For holding pens in lairage Grandin (1993) recommended placing pens at an angle of 60 - 80º angle to central walkways as this reduced the likelihood of animals bumping into gateposts or slip when exiting the pens.

Sliding gates, drop gates and normal gates should always be maintained in good working order as animals can get seriously injured when wedged between gates and gateposts or when hit by drop gates (Grandin, 2007a). In the present investigation a large percentage of bruising was seen to occur in the stun box and was caused by the tail gate dropping onto the haunches of the animals entering. Gate latches should be fitted at a height where animals are unlikely to come into contact with them. With cattle, the area between 70 and 135 cm above the floor is considered the bruise hazard zone (Grandin, 2001).

Where solid fences are installed, fencing material such as sheet metal should always be installed on the side where cattle are held to prevent them from catching any parts on the fence posts. Where cattle are handled on both side of the fence a belly rail can be installed to prevent injury (Grandin, 2001).

Loading and off-loading facilities have the potential to cause poor welfare when not built according to the species requirements. Another factor to consider during loading/un-loading is the distances between these ramps and the truck floor height. The angle of loading and off-loading ramps for cattle should not exceed 20º. Furthermore, Eldridge *et al.* (1989) showed that off-loading animals via a 120 cm wide off-loading race (at 20º angle) led to less slips and falls than off-loading over a narrower race (70 cm). Loading on the other hand, is achieved more securely over a single file race as this prevents animals from turning around and thereby causing disruption and injuries.

The design of livestock transporters around the world will be influenced mostly by the distances covered, the prevailing weather conditions and applicable legislations and/or code of practices (Knowles, 1999). One of the most important aspects of vehicle design, except physical safety of the animals, is ventilation of the loading areas. Insufficient ventilation can quickly lead to heat stress and dehydration. In transports that generally last less than 8 hours the most commonly seen system is free ventilation (i.e. open trucks; Anonymous, 2002). One of the pitfalls of this type of ventilation is the fact that the moment a vehicle stops moving ventilation ceases. In the case where double decked trucks are used with free ventilation the space above the head of the loaded animals must be sufficiently high (20 cm) to facilitate good ventilation (Anonymous, 2002).

Other aspects of vehicle design include compartmentalization in order to segregate certain groups of animals as well as penning smaller groups on the truck. The advantage of penning individual or small groups during transport have been investigated by Lambooy and Hulsegge (1988) who found that heifers penned in pairs had more traumatic events during a journey compared with heifers transported loose or in groups of 8 animals per compartment. The structures used to create different compartments in the loading area must be built from solid materials and in such a manner as not to cause injury to animals.

6.4.4 Stockmanship

Stockmanship is a word which describes the ability of a person to handle animals. Rough handling is one of the main reasons for bruising in cattle (Grandin, 1999). The excessive use of sticks and electric goads as well as loud noises will agitate animals and they will react to these events by trying to flee. Highly agitated animals are more likely to bump into gates, railings and each other which will result in bruising and poor welfare; these animals are also more likely to attack a handler when feeling cornered. As mentioned above, if animals are suddenly confronted with a novelty, they tend to baulk and refuse to move forward especially in cases where there are high visual contrasts (shadows, water reflections, etc.) or sudden movement (Grandin, 2007a). The reaction of the animal often influences the reaction of the handler and bad tempered animals often elicit bad handling as a response (Jarvis *et al*., 1995). This is a negative spiral which needs to be broken and which can be addressed by training handlers in terms of animal behaviour. Furthermore, it has been shown that cattle can be habituated to handling especially when their first experience is a positive one (Grandin, 2007a). Fordyce (1987) reported that training young calves produced calmer adults that were easier to handle. The training done in the above mentioned trial included walking quietly among the weaner calves in their corral, working them through a race and teaching them to follow a lead horseman. Inherent animal behaviour which can be utilized to improve ease of handling include, herd instincts, consideration of individual animal temperament, personal space of the animal (flight zone) as well as taking cognisance of their senses such as hearing, vision and smell.

Most domestic livestock are herd animals by nature and herd behaviour is an aspect which when utilized advantageously can reduce stress during animal handling. In most groups of animals there are so called leaders, often they are those animals which enter a raceway first. Where animals are given time to follow the leaders at their own pace they will be less likely to injure themselves. Care should be taken to prevent animals being separated from the group as this poses a threat not only to the animal which will be more likely to injure itself trying to rejoin the herd but also to any handlers trying to move it (Grandin, 2001). Where an animal refuses to move by itself, adding others and then moving the whole group often works best. Crowding animals too tight in raceways or crowded pens, especially extensively raised animals, will cause them to bunch up in corners bumping into each other and structures in their attempt to avoid contact and this causes stress and bruising.

There are genetic differences between livestock breeds which will result in different behaviour to the same stimuli. *B. indicus* breeds are more excitable compared with most *B. taurus* breeds, while European continental breeds are more excitable than British breeds (Grandin, 2001). However, variation in individual animal temperament is often higher that variation between breeds. In the Namibian context it should also be kept in mind that nearly all animals are raised under extensive conditions and extensive conditions are by nature very variable compared to most intensive conditions (Manteca & Ruiz de la Torre, 1996) thus differences in animal behaviour vary accordingly.

Every animal has a flight zone; if this zone is penetrated by a person the animal will move away. The distance the animal moves away from the source of disruption is called the flight distance. This distance is larger in extensively raised animals compared to animals raised in close contact with humans (Grandin, 2007a).

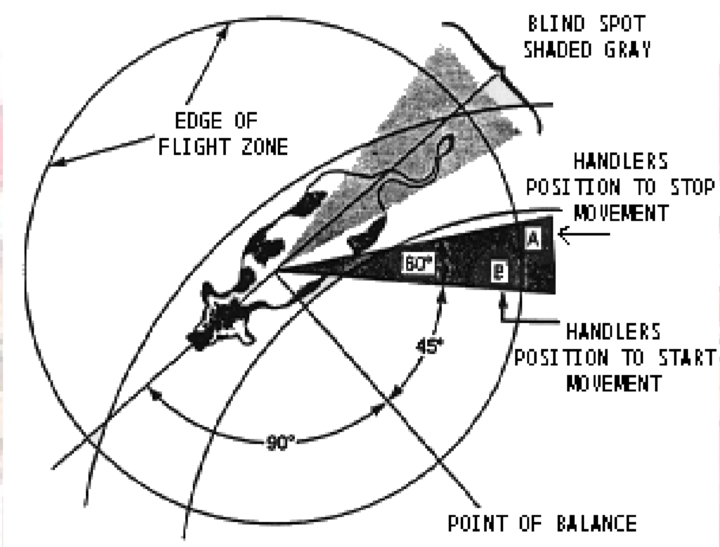

Figure 2 Handler position for efficiently driving a single animal (adapted from Grandin, 2001)

Deep penetration of the flight zone will cause an animal to panic. Furthermore, cattle have a point of balance which lies at the height of their shoulder. If a handler wants an animal to move forward he/she should remain behind the point of balance while the animal will move backwards if the handler stands in front of the point of balance as illustrated in Figure 2 (Grandin, 2007b).The point of balance can be utilized to advantage when moving animals through a single file, straight raceway as depicted in Figure 3. The handler should walk quickly past the point of balance in the opposite direction of the desired movement. As he/she crosses the point of balance, the animal will move forward.

As mentioned above, hearing in animals is much more acute than in most humans. Loud noises like yelling and banging objects will cause considerable stress and animals should at all times be handled quietly (Grandin, 2001).

Goads used for driving livestock should always be handled with integrity and only in situations that warrant their application, i.e. only on animals where the use will result in desired animal behaviour. They should never be used on the face or anal-genital regions of an animal. The use of electric goads must be limited to the necessary minimum (Knowles et al, 1994).

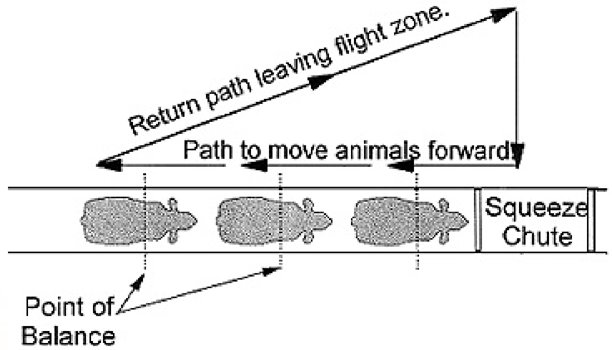

Figure 3 Handler movement pattern to keep cattle moving into a squeeze chute or restrainer (adapted from Grandin, 2001)

A driver's knowledge about transport factors such as loading density, ventilation and wind chill as well as the driving style will have a huge impact on the welfare of the animals transported. Cornering and breaking are the two driving events most closely associated with loss of balance and animals going down (Grandin & Gallo, 2007). Where loading densities are too high, downer animals will struggle to get back up as other animals will immediately take over the standing space that opened up (Tarrant *et al*., 1992). Where the loading densities are too low braking will be the more important driving event as animals struggle to maintain their balance as the support of pen mates is not available (Eldridge & Winfield, 1988).

The ambient temperature and travel speed determine the wind-chill factor felt by the animals on open, free ventilation vehicles (see Table 6.2). Drivers should be aware of this influence as temperature fluctuations of more than 5.6ºC in a 24 -72 hours before slaughter leads to decreased meat quality (Scanga *et al.*, 1998).

Table 6.2 Wind-chill factors at different travelling speeds and ambient temperatures (adopted from Anonymous, 2000)

Speed (km/h)	**Ambient air temperature (ºC)**								
	25	**20**	**15**	**10**	**5**	**0**	**-5**	**-10**	**-15**
8	25	19	14	9	4	-2	-7	-12	-17
16	23	17	11	3	-2	-7	-13	-18	-24
24	21	15	8	2	-5	-11	-17	-24	-30
32	20	13	7	0	-7	-13	-20	-26	-33
40	19	12	6	-1	-8	-15	-22	-29	-35
48	18	11	4	-3	-10	-17	-24	-31	-38
56	17	10	3	-4	-12	-19	-26	-33	-40
64	16	9	2	-5	-13	-20	-28	-35	-42
72	16	8	1	-6	-14	-21	-29	-36	-44
80	15	8	0	-8	-15	-23	-30	-38	-45

* These parameters are applicable to dry animals only. The wind-chill factor is exacerbated when animals are wet.

All the above mentioned problems can be addressed with education (staff training), good management and monetary incentives which promotes good animal welfare practices. Broom (2000) showed that animal welfare was improved where those responsible for the animals during transport were given a monetary incentive which would result in better welfare. In another study by Guise (1991) drivers received bonus payments according to their fuel efficiency. Drivers travelled at reduced speed and accelerated less which improved welfare and meat quality. Furthermore, companies and stakeholders of the livestock industry should on employment consider the personal attitude of potential employees, destined to be involved with the handling of live animals, towards animals. People who consider animals as sentient and able to feel fear and pain will approach animals much more considerate than someone who sees them as a means to an end.

6.4.5 Fitness of animals for transport and segregation during transport

Before loading and commencement of journey an important aspect influencing welfare is determining whether an animal is fit to be transported. According to the Meat and Livestock Association of Australia (Anonymous, 2006b) an animal is fit to be loaded for transport to sale yards, abattoirs, or any other destination if it:

- is strong enough to undertake the journey;
- can walk normally, bearing weight on all four legs;
- is not suffering from any visible disease or injury that could cause it harm during transport;
- can keep up with the herd both at loading and unloading;
- is not in late pregnancy.

Furthermore, when preparing animals for transport segregating specific groups or individual animals has the potential to improve the welfare of animals during transport and in lairage by preventing aggressive or sexual animal behaviour like butting and mounting. The recommendations made in this regard in the revised FAN Meat guidelines (personal communications: Dr. Thalwitzer) identified the following groups or individual animals which should be kept apart during transport:

- weak and strong animals;
- very small and grown animals;
- horned and de-horned/polled animals ;
- bulls and cows;
- calves and unfamiliar older cattle,
- and known aggressive, bad tempered individuals.

Similar segregation groupings should be maintained in lairage, especially where intact males and aggressive individuals are concerned. Research has shown that especially mounting behaviour in lairage had a negative effect on meat quality as it increased the appearance of DFD meat (Tarrant & Grandin, 2000).

6.4.6 Loading, transportation and unloading to minimizing stress and injuries

Of the events identified as most critical during handling and transport as pertaining to animal welfare are loading and off-loading, loading densities and journey duration.

During the course of transport, loading and off-loading have been identified as the most stressful parts of the event for most livestock species (Broom, 2005). Novel experience, forced exercise, steep loading ramps, vehicle conditions and close confinement on vehicle can cause fear and pain (Grandin & Gallo, 2007). The reaction of extensively raised cattle to these events will be different than in animals raised in close proximity with humans (Grandin, 2007c). Kenny and Tarrant (1987) reported increased heart rates during loading and off-loading in Friesian bulls, while heart rates have been reported to go down after the initial stages of the journey indicating that animals adapt to transport (Honkavaara *et al.*, 2003).

Stocking densities have a high influence on animal welfare during transport. They do not only determine the physical amount of space available to an animal on the truck but also affect the ventilation in the loading area (Randall, 1993). Too high or too low loading densities have been associated with increased bruising of a magnitude of 4 and 2 times that seen in intermediate densities (Eldridge & Winfield, 1988). This study thus confirmed that there is an optimum loading density however more research will be needed in order to determine these optimum densities, as factors such as animal size, conformation, weight, age and horns as well as ambient temperatures and average distances/duration of journey all influence optimum stocking densities and need to be adjusted according to individual country's circumstances and transport conditions (Knowles, 1999). The recommended stocking densities for cattle in the revised FAN Meat guidelines are the same as those given under the Australian model code of practice, they are somewhat higher than those adopted by the EU and are presented in Table 6.3.

Table 6.3 Space allowances as recommended by the revised FAN Meat guidelines (personal communications: Dr Thalwitzer 2009)

Weight (kg)	**Loading densities (m^2)**
< 250	0.5 - 0.6
250	0.77
300	0.86
350	0.98
400	1.05
450	1.13
500	1.23
550	1.34
600	1.47
650	1.63

Although extensive research has gone into the effect of journey duration on animal welfare aspects there is a lack of agreement on what times are deemed acceptable or not. Journey duration is affected by factors like road conditions and ambient temperatures and the most important associated animal welfare factors are feed and water deprivation, physical exhaustion and thermal stress.

Tarrant, Kenny, Harrington and Murphy (1992) reported that 600 kg steers were noticeably tired and dehydrated after a 24 hour journey. Warriss *et al.* (1995) transported cattle (350 kg) for 15 hours and did not find that the journey duration had any negative impact on the animals' welfare. In another experiment 31 hour transport was compared to 24 hours and the authors concluded that from an animal welfare point of view a 24 hour journey is more appropriate as animals showed signs of dehydration and tended to lie down during the last part of the 31 hour journey (Knowles, Warriss, Brown & Edwards, 1999). In countries like Australia where transport takes place over extended periods of time recommendations are often reflective of maximum periods of water deprivation. In Europe normal journey times are limited to eight hours. This can be extended if more elaborate transport vehicles are used, compulsory rest periods are maintained and approval is granted by the responsible authorities. Table 6.4 gives a summary of the recommended journey times in the EU, Australia and Namibia.

Table 6.4 Recommended journey times for transport of cattle

	Normal (hrs)	**Extended (hrs)**
EU	8	14 + 1 + 14
Australia	36	48
FAN Meat	8	8 + 1 + 8

The inclusion of rest stops during transport is controversial and it has been suggested that the additional off-loading and re-loading procedures and novel environment of the rest facilities might lead to increased stress and the rest stop as such might just prolong the journey time without any benefits to the animals (Grandin & Gallo, 2007).

6.5 Quality of Namibian meat

The Namibian beef industry is faced with the same meat quality problem of inconsistent beef tenderness as reported from many other countries. Similarly, the final meat quality (especially tenderness) is not only influenced by the ante mortem stress experienced by the animals, but also by genetic factors (O'Connor, Tatum, Wulf, Green and Smith, 1997). The results on meat quality from this investigation emphasize that there is room for improvement in the meat quality of the typical Namibian breeds. The fact that meat from the Brahman cross animals was consistently less tender than the other breeds does not necessarily reflect only breed effects but also production systems. Most animal from communal areas are Brahman crossbred animals raised under much more challenging conditions than those produced from commercial farms. This aspect was not considered in the current study and more research is needed to determine whether animals from different production backgrounds in Namibia differ in terms of meat quality. Furthermore, aspects like post-mortem electrical stimulation and chilling regimes which were not considered in the current study have the potential to greatly influence meat tenderness (Ferguson, Bruce, Thompson, Egan, Perry & Shorthose, 2001).

6.6 Conclusion

This study addressed part of the Namibia transport practices, namely the transport to slaughter at the Windhoek export abattoir as well as the meat quality of animals slaughtered at the same facilities. However, data collected for this trial relied in part on secondary data (questionnaires and interviews) which might draw a superficial picture of the farming practices and transport event and there is thus room for a more in-depth study of these two areas in specific.

All in all it seems that the conditions during transport are more important to welfare than length and duration of transport alone. It must however be kept in mind that the distances and duration of journeys reported in this study do not represent the much longer distances transported in the event where animals, especially weaners, are exported live to neighbouring countries. Welfare might be seriously compromised on these longer journeys as the journey times most definitely exceed eight hours. In these journeys, borders need to be crossed and the larger parts of the journeys take place on foreign soil. This creates a problem with welfare legislation and guidelines as it is not clear which countries rules and legislations apply to the animals in transit. Rest stops are often not feasible as the threat of transmission of diseases, especially foot and mouth, are increased where animals are off-loaded at facilities which see a lot of thoroughfare. Furthermore, lengthy stops at border crossings will increase the risk of heat stress as the ambient temperatures in summer can reach units above 35º Celsius. More research is needed in this area of cattle transport.

There is a definite need for the Namibian meat industry to explain to all the stakeholders the reason behind the animal welfare demands the industry is challenged with as well to educate these stakeholders on how to achieve these specific standards in practice. The financial costs incurred by bruising should be brought to the attention of all participants of the Namibian beef industry in order to emphasize the urgency of this matter.

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Appendix

Addendum A

i) Questionnaire used in telephone interviews with producers.

Date of loading:_______________

District of production: ____

Distance the animals travel from farm to abattoir:

Total ____________ (km)

Tar ____________ (km)

Gravel ____________ (km)

Is the road to Windhoek

rather flat? □

rather hilly? □

How many hours before loading were the animals rounded up (to stand without food)? _________________________

Which of the following activities were done directly before loading?

Sorting □

Weighing □

Branding □

Insert Ear tags □

If branding took place just prior loading, how was the animal immobilized

By an electric immobilizer □

By pushing up the tail □

In neck clamp □

How frequently are the animals handled during a year

Once □

Twice □

More than twice □

Please describe the predominant handling procedures

____

____

____

What is the dominant of cattle breed you farm with? __________________________________

ii) Questionnaire put to drivers on arrival at abattoir.

Date _______________ Time of arrival _________________

Transport company name: ____

How many animals were loaded onto

Truck ____________?

Trailer ____________?

How long did the loading on-farm take? _________

Rate the loading facilities on the farm:

Excellent □

Good □

Poor □

Was an electric prod used during loading?

Yes □

No □

How many hours did the transport take? ___________

Was there any delay during the journey?

Yes □

No □

If yes what was the reason for the delay?

____

____

____

How long did the delay last? __________________

Did the animals lie down during transport?

Yes □

No □

How often did the truck stop to raise animals that lay down? __________

How do you raise the animals lying down?

Electric goad □

Stick □

Other □

The weather was

Rainy □

Dry and hot □

Dry and cold □

iii) Observations done on off-loading

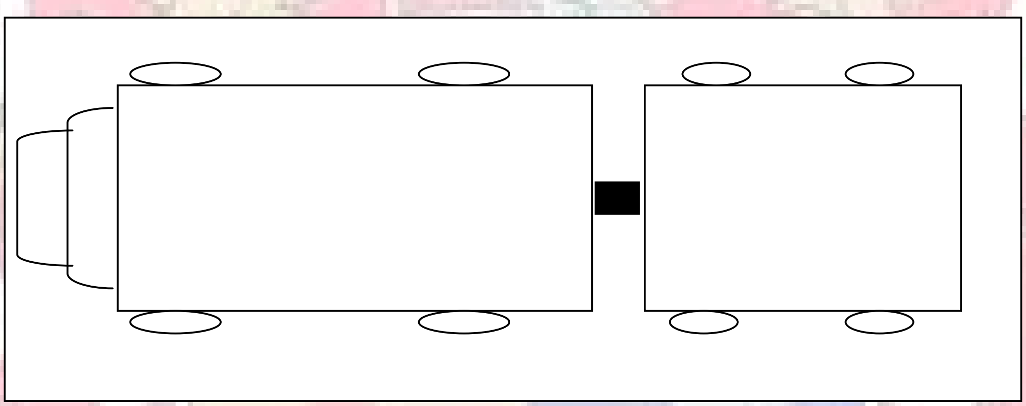
Pen No. : ______________________ Date/Time________________________

On arrival check:

1) Number-plate of Truck: ________________Trailer No-plate: _______________________
2) Alpha-no. of cattle Producer: _____________________________
3) No. of animals lying on the truck: __________________
4) If possible record the IDs of downed individual:__________________________________
5) Did the truck seem
   - crowded ☐
   - comfortable ☐
   - spacey ☐

6) Describe compartments:

Measure length and breadth of compartments



7) No. of animals per compartment:

A) __________ B) __________ C) __________ D) __________ E) __________

(If no sub-divisions, the truck-compartment is noted as A and the trailer compartment as B)

Describe the door vs. floor space: ____

Describe how animals moved:

- Calmly ☐
- prodded with electric prod ☐
- Vocalisation ☐

How many animals slipped during offloading? ___________________

How did the animals move to the lairage pens?

Calmly ☐

Ran ☐

had to be prodded electric prod ☐

Describe the condition of the animals

- Alert but calm ☐
- Restless and nervous ☐

Score amount of dung in the truck

- Excessive ☐
- Moderate ☐
- Little ☐

Describe truck floor

- Flat metal sheet with ridges ☐
- Welded metal mash ☐
- No covering ☐

iv) Lairage observation sheet

Lairage						
Pen no.		**No. of animals in pen:**			**Breed type:**	
Date	**Min. Temp.:**	**Rain** how long:			**No. of** Males	♂ Ox
	Max. Temp.:	how hard:			Females	
Describe condition of		Good	Good/Medium	Medium	Medium/ Poor	Poor
		Horns		□		
		Smooth and shiny		□		
		Woolly		□		
		Dirty and dusty		□		
		Stomach thin		□		
		Eyes sunken		□		
Were animals branded			Yes	No		
	Repetitions		**1**	**2**	**3**	**4**
How long before they drank water?						
No. of animals drinking water:						
No. of animals lying down resting:						
No. of animals chewing cud:						
No. of animals lying down due to						
	Specific animal No.					
	Describe abnormality					
No. of animals fighting:						
	Reason:					
No. of animals vocalizing						
	Reason					
Animals mounting/riding one another:						
(give Specific animal No. of the						
Comments						

Addendum B Lairage layout